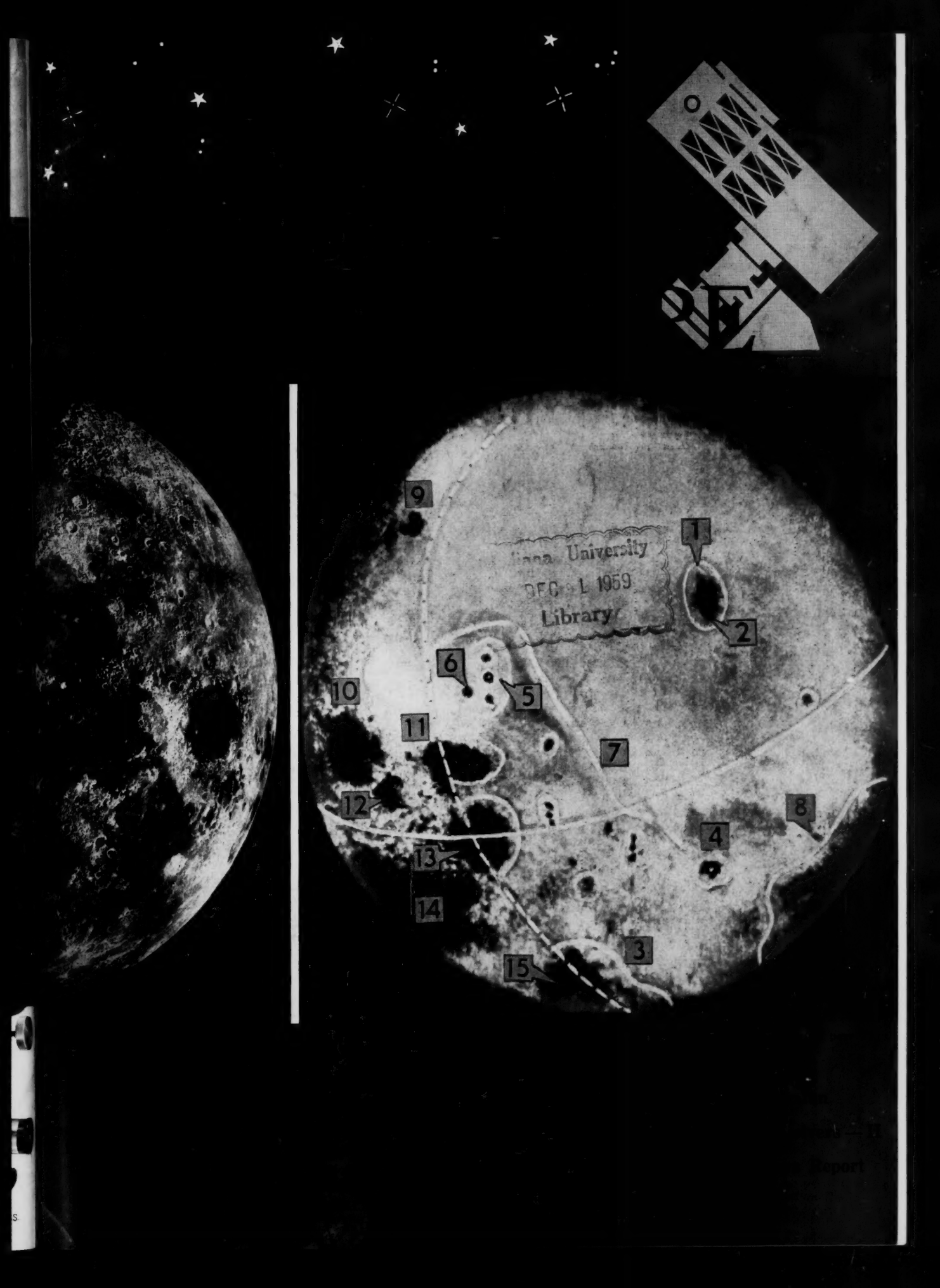

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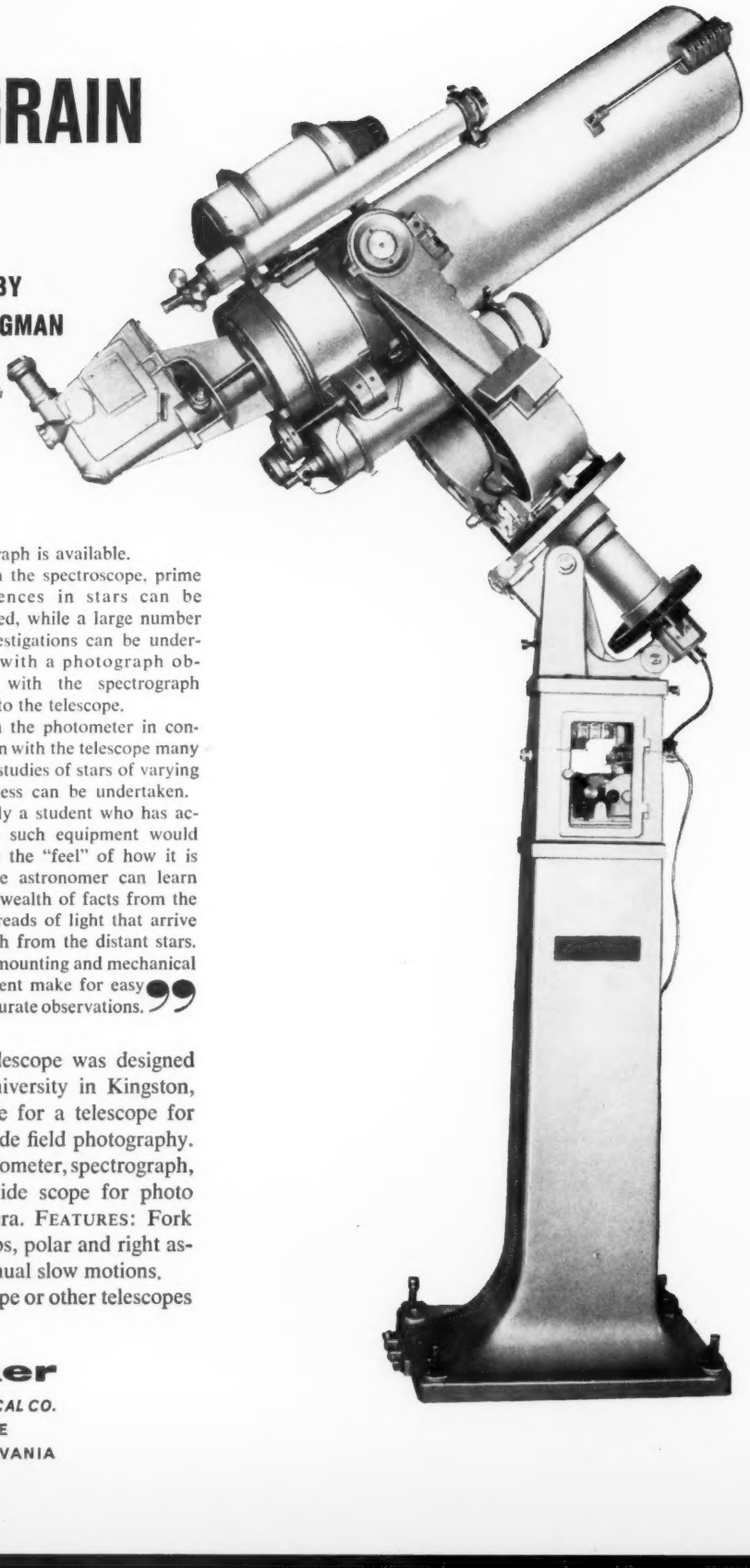
TEACHING WITH A FECKER 15″ CASSEGRAIN

COMMENTS BY DR. N. E. WAGMAN

Director, Allegheny Observatory of the University of Pittsburgh



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Sky and TELESCOPE

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Vol. XIX, No. 2 DECEMBER, 1959

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COVER: The photograph at the right, taken on October 7th by the Soviet space probe Lunik III, is man's first view of the far side of the moon. To the left is part of a conventional picture of the near side, showing some features that overlap the view from space. Though the moon on October 7th was a few days after new, as seen from Earth, the phase presented to Lunik III was about four days before full. The dashed white line indicates the edge of the normally visible hemisphere, and the heavy solid line represents the moon's equator. Photograph courtesy Wide World Photos. (See page 72.)

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Lunar Occultation Observations by Amateurs

A DRAMATIC SPECTACLE, one that every amateur astronomer should sometime see in a telescope, is the abrupt disappearance of a bright star as the moon passes in front of it. Such an event gives a greater satisfaction if the observer times it precisely – a simple operation which nevertheless requires some care if it is to be scientifically useful.

The moon moves eastward among the stars, traveling its own diameter in about an hour. Because an occultation of a star can be timed to a fraction of a second, observations of this kind provide a simple way of telling whether the moon is ahead of or behind schedule.

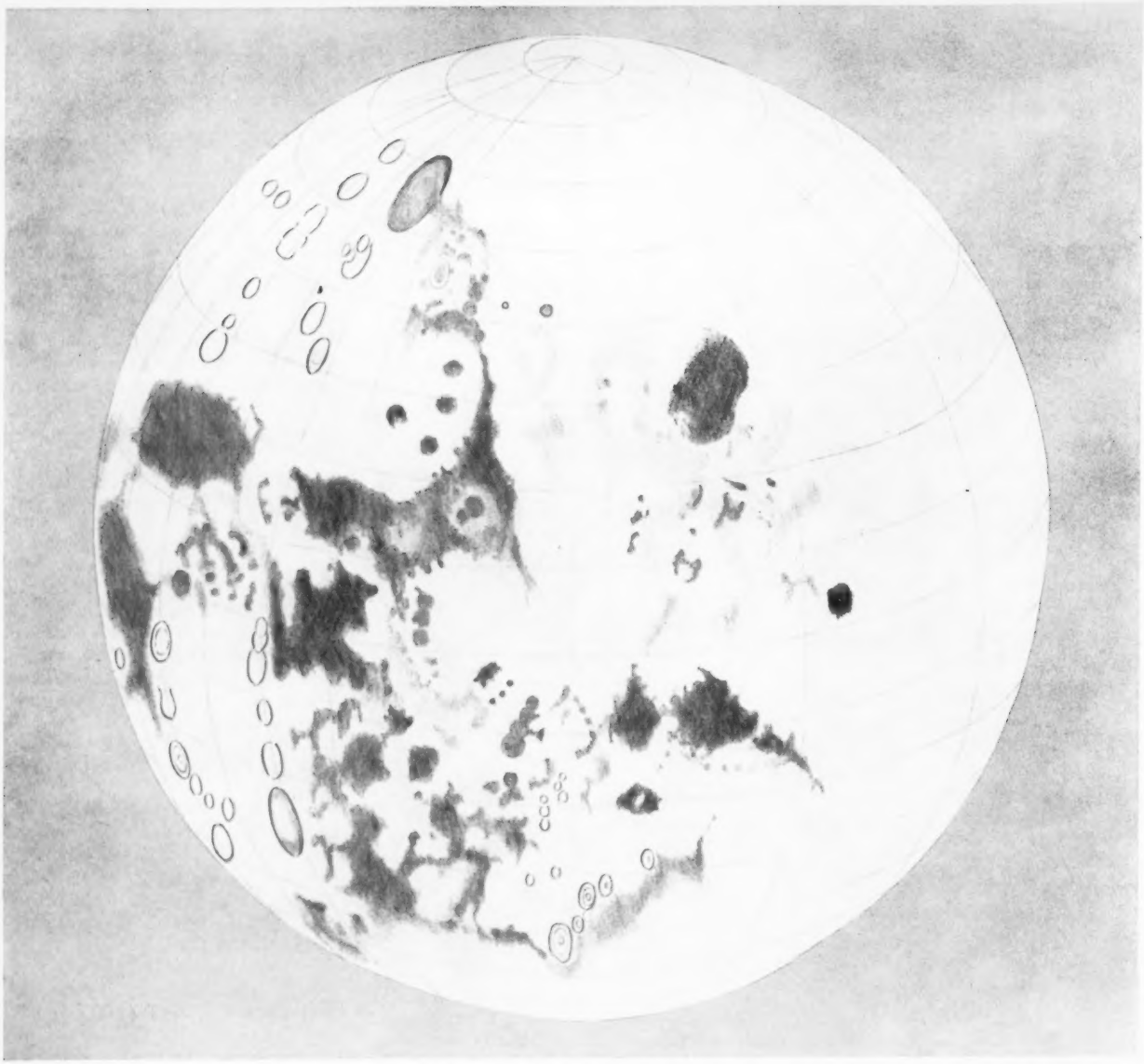
From this has developed an effective system of amateur-professional co-operation. Each year many hundreds of occultations are timed by amateurs, who send their observations to H. M. Nautical Almanac Office in England to be worked up, and the observers receive an annual report on studies of the moon's motion. This co-operation is described in Flora McBain Sadler's article in this issue, and the predictions of occultations for 1960 in the United States and Canada are given in the supplement at the center of the magazine.

One widely used method of timing an occultation requires only a telescope, a stop watch, and a clock that is compared with radio time signals before and after the event. At the instant the star disappears (or reappears), the observer starts the stop watch. Then, precisely as the clock indicates the beginning of the next minute, the watch is stopped. Subtracting the stop-watch reading from the indication of the clock gives the time of the occultation, which still must be corrected for the clock error found from the radio time signals.

Several precautions need mention. The stop watch should be of good quality, starting without a jump. Its rate should be carefully determined, so that a correction can be applied if necessary. Because of their erratic fluctuations, electric clocks are unreliable as time standards when a precision of 0.1 second is sought.

High accuracy can be obtained photoelectrically, if the observer has the proper electronic equipment. The light of the star falls on a photocell, its output tracing a curve on a high-speed recorder, which also registers second-by-second radio time signals. In this way the disappearance of a star can be timed to about 0.01 second.

The American Association of Variable Star Observers has an active occultation committee. Further information on observing techniques can be obtained from its chairman, Roy A. Seely, 1060 Amsterdam Ave., New York 25, N. Y.



In this drawing, Ernst E. Both has combined known areas on the moon with the ones first observed by the satellite Lunik III. The system of selenographic co-ordinates already standard for the near side of the moon has been extended to cover the far side as well. Compare this drawing with the front-cover photograph and with the key chart opposite.

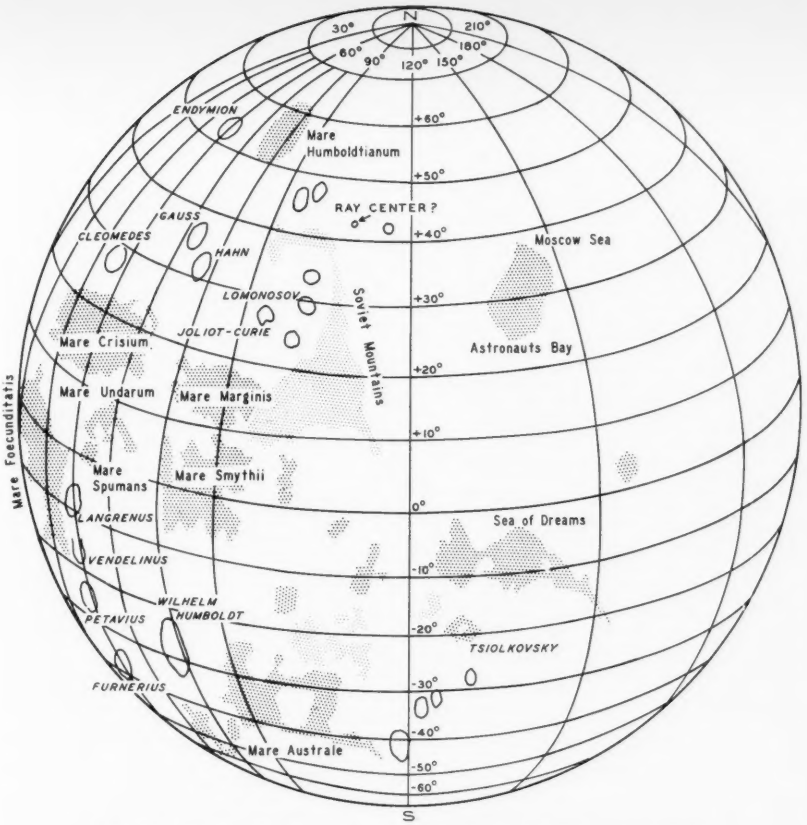
First Photograph of Moon's Far Side

LIKE COLUMBUS on October 12, 1492, Lunik III on October 7, 1959, obtained a tantalizing first glimpse of a new world. Only three-fifths of the moon's surface had been observed before, some of it very obliquely and under rare conditions of libration. Now, about three-fourths of the previously unseen portion has been recorded in photographs from the Russian satellite.

The picture on the front cover is comparable in quality with daguerreotypes of the moon taken in the 1840's. As told on page 91, the film was exposed with a small camera when it was about 40,000 miles from the moon, development taking place automatically within the satellite. Then the negative was televised to earth, with a scan resolution of about 1,000 lines per inch. After reassembly, the picture was transmitted by radio from Moscow to the United States, reprocessed, and photoprints made.

Each step in this complicated chain has lost some detail in the photograph, and doubtless certain features have been effaced. Also, because of the many hands through which the picture has passed, there has been an unknown amount of retouching. For these reasons, much may be discovered on the photographs under study in Russia that is not apparent on the samples now available in this country.

Nevertheless, the latter have been used by Ernst E. Both, curator of astronomy at the Buffalo Museum of Science, to draw the preliminary map of the moon's far side reproduced here. On his key chart, longitude 90° west represents the edge of the moon at average libration, the region visible telescopically under extreme conditions extending to about 98°.



KEY TO FRONT COVER AND ERNST BOTH'S DRAWING

Important features on the drawing by Mr. Both are identified in this chart, as well as all of the numbered items on the front-cover picture, which are: 1, Moscow Sea, 185 miles wide; 2, Astronauts Bay; 3, continuation of Mare Australe; 4, Tsiolkovsky crater; 5, Lomonosov crater; 6, Joliot-Curie crater; 7, Soviet Mountains; 8, Sea of Dreams; 9, Mare Humboldtianum; 10, Mare Crisium; 11, Mare Marginis; 12, Mare Undarum; 13, Mare Smythii; 14, Mare Foecunditatis; 15, Mare Australe.

Features to the left of this are previously known, and are labeled with their accepted names.

But, in the new areas farther right, the names are the ones proposed by Soviet scientists. Unquestionably, the act of lunar discovery implies a right to assign names, but the International Astronomical Union presumably will rule on the individual designations. For example, the formation Joliot-Curie may be identical with one long known as Mare Novum, Mr. Both points out.

The moon's farther side appears to be mainly continental (mountainous) in character, with few of the large dark plains known as seas. The most extensive of these, the Sea of Dreams, appears to be a continuation of the great chain of maria (Mare Tranquilitatis, Serenitatis, Imbrium, and Oceanus Procellarum) that, half a century ago, J. Franz conjectured might girdle the moon.

The Soviet photographs mark the first serious beginnings of what may be called *trans-selenography*, the science of the moon's hitherto hidden side. Some future steps in this field can be forecast. Evidently, much more detailed information will be available when Soviet astronomers have completed their analysis of the existing pictures. There is still a considerable area beyond the eastern limb of the moon awaiting a first view by future space probes.

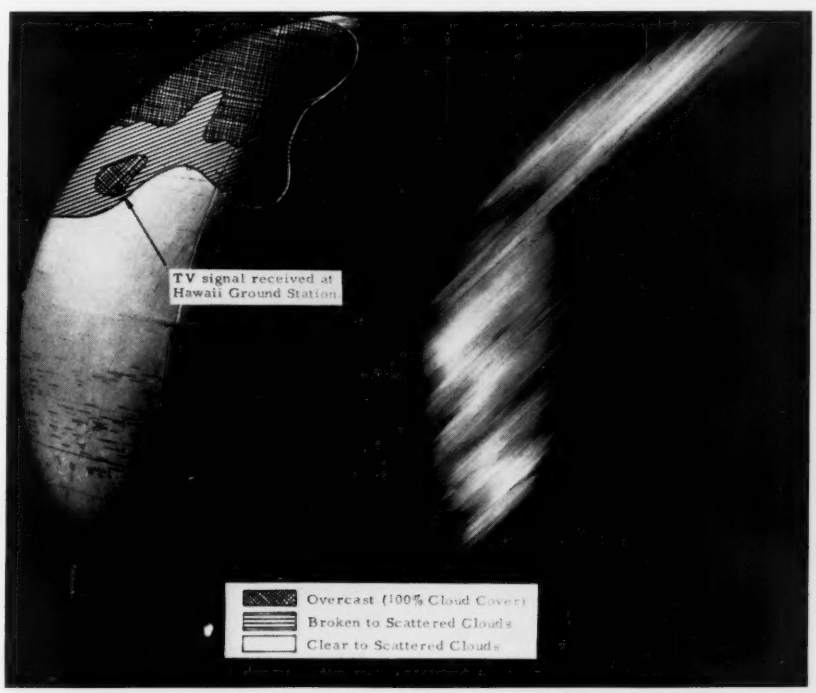
One important task is the determination of precise selenographic longitudes and latitudes of features on the far hemisphere. This will involve measurement of overlapping photographs, in order to extend entirely around the lunar globe the coordinate network of the nearer face.

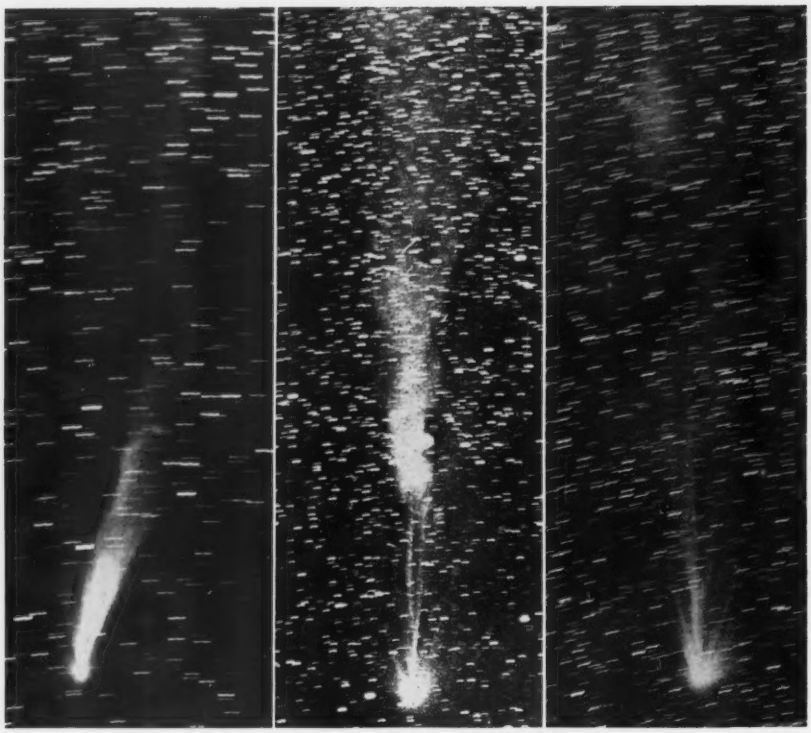
SATELLITE SECURES WEATHER PICTURE

An important advance in global meteorology was foreshadowed on August 14th, when a television-type picture of the earth was transmitted from an altitude of 17,000 miles by the "paddlewheel" satellite Explorer VI (see October issue, page 673). A 2-inch reflector focused the earth's image on a photocell. One element of the picture was transmitted at each rotation of the satellite, 64 elements making a line.

As the satellite orbited over Mexico, 110 lines were scanned in about 40 minutes, providing a crude view of the central Pacific Ocean and its cloud cover. The television system in the satellite weighed only two pounds. The signals were received at the South Point, Hawaii, tracking station.

Along with the satellite picture, the National Aeronautics and Space Administration released the view of a globe illuminated to match the earth, and showing the actual cloud conditions known from conventional observations to have existed over the Pacific area at the time.


TV signal received at Hawaii Ground Station
Overcast (100% Cloud Cover)
Broken to Scattered Clouds
Clear to Scattered Clouds



Morehouse's comet, photographed, left to right, on September 30, October 1 and 2, 1908, by E. E. Barnard at Yerkes Observatory. This comet was among the most active known, one striking transformation being illustrated here. The well-formed tail in the first picture has become detached by the next night, and on the following date it has receded far from the comet's head. Because the camera tracked the comet and not the stars, the latter appear as trails, whose length indicates the comet's motion during the exposure.

Comet Morehouse 1908 III

OTTO STRUVE

*National Radio Astronomy Observatory**

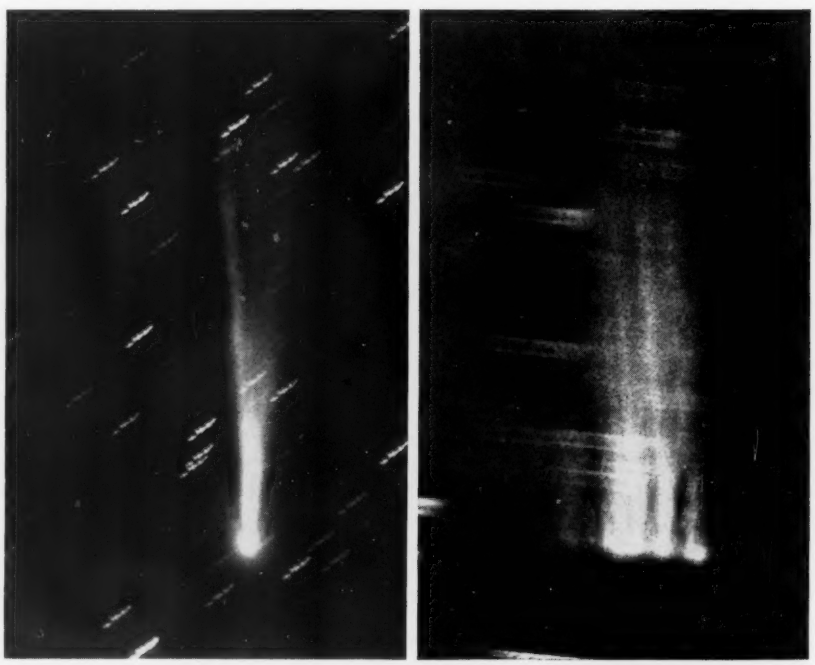
ALTHOUGH 51 years have elapsed since its discovery by D. W. Morehouse, with the 10-inch Bruce photographic refractor at Yerkes Observatory, Comet 1908 III is remembered as one of the most famous of this century. It was a bright, well-photographed object whose extraordinary behavior is still being pondered by astronomers who seek to explain the tails of comets.

As W. L. Kennon has remarked, Morehouse's comet "is remarkable because of the rapid changes in its tail formation and because of its sudden outbursts in brightness. On one occasion, within two days, it discarded one tail and formed another." It was extensively photographed at Yerkes by E. E. Barnard (some of whose pictures are reproduced here), by Max Wolf at Heidelberg, and by many other observers.

In general, the photographs show that Comet Morehouse had a long, irregular tail, directed away from the sun. In October, 1908, however, the tail deviated by about seven degrees from the prolongation of the straight line from the sun to the cometary nucleus. The detailed structure of the tail on October 29th is shown in the recent drawing by P. Stumpff, which may be compared with the general appearance of the small picture for that date.

The motion of material in comet tails, so strikingly illustrated by 1908 III, has interested astronomers for well over a century. Since all *normal* tails of comets point away from the sun, F. W. Bessel suggested in 1836 that the particles forming them experience a force of repulsion from the sun, this force varying inversely as the square of the distance from the sun. The nature of the repulsion was not known in Bessel's day, but later, and until about seven years ago, it was usually attributed to the pressure of the sun's radiation.

*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.



E. B. Frost and J. A. Parkhurst obtained these records of Comet Morehouse on the same night, October 29, 1908. Compare the direct photograph (left) with the Stumpff drawing on the facing page. The comet's spectrum (right) was obtained with a prism over the telescope objective, which is still an important method of cometary observation. The images of the comet are those of its constituent gases, including molecular nitrogen, carbon monoxide, and cyanogen. All photographs with this article are from Yerkes Observatory.

On November 16, 1908, Comet Morehouse's tail seemed composed of sheets of luminous gas, with a few bright streamers. Though photographically brilliant, because of its blue light, this comet was relatively faint visually.

For very small particles of matter, radiation pressure may equal or become much larger than the force of the sun's gravitation. The former depends on the area of the particle that is turned at right angles to the sunlight falling on it. The latter force depends on the mass of the particle.

At the earth's distance from the sun, radiation pressure from sunlight is 4.5×10^{-5} dyne per square centimeter, while the attraction by solar gravity is 0.58 dyne per gram. It is easy to compare these opposing forces if we consider particles that are opaque, solid spheres, each of radius r, cross section A, mass M, and density ϱ. If R is the ratio of the force of radiation to that of gravitation, then

$$R = 4.5 \times 10^{-5} A/0.58\, M.$$

Since A is πr^2, and M is $4\ \pi r^3 \varrho/3$ the expression may be written

$$R = 4.5 \times 10^{-5}\ \pi r^2/0.58\ (4\ \pi r^3 \varrho/3),$$

which reduces to

$$R = 5.8 \times 10^{-5}/r\varrho.$$

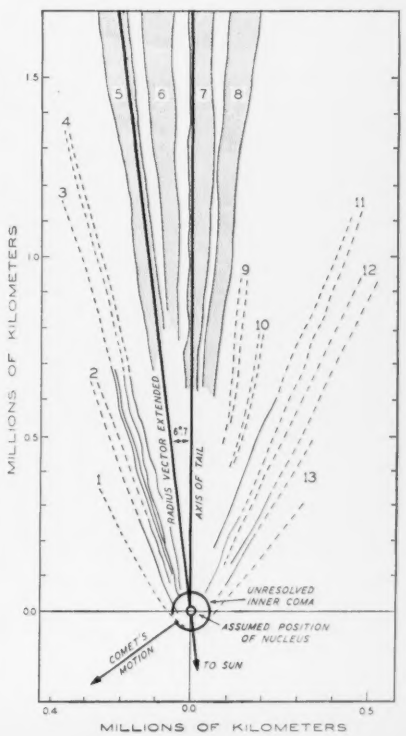
Thus, if the particle's density were 5.8 grams per cubic centimeter, about the average density of the earth, R would be $10^{-5}/r$. The two opposing forces of radiation pressure and gravitation would balance for particles of radius 10^{-5} centimeter. An object of this size would move in a straight line depending only on its initial speed and direction of motion.

Should the particle have a radius smaller than 10^{-5} centimeter, radiation would prevail over gravitational attraction, and the orbit would be a hyperbola, convex to the sun. For larger values of r, gravitation exceeds radiation, and the orbit is an ellipse. Particles having radii of about a centimeter are not noticeably affected by radiation pressure, and for asteroids, satellites, and planets its net effect is negligible.

Although we have considered only particles at one astronomical unit from the sun, the formula is valid at other distances, because radiation pressure, like gravitation, varies as the inverse square of the distance.

Ordinary interplanetary dust particles, such as those giving rise to the zodiacal light, are not much smaller than 10^{-6} centimeter in radius; otherwise they would produce unobserved diffraction effects or, if very small, would behave as molecules. Hence, for dust in comet tails, we can hardly expect the ratio R of forces ever to exceed 10. Some comet tails have been observed to show continuous spectra, and presumably consisted mainly of dust shining by reflected sunlight. For these, the repulsive force may have been about twice as large as the gravitational force.

However, most cometary matter consists not of solid dust grains, but of gases of different kinds of molecules, such as ion-



This diagram of the system of streamers in the tail of Morehouse's comet on October 29, 1908, is based on a chart by P. Stumpff in the German journal "Zeitschrift für Astrophysik." On the original photograph from which his drawing was made, the tail appeared 2,800,000 kilometers long. Of the 13 recognizable separate streamers, those labeled 5 through 8 formed the main tail. Faintly bounded features are dashed, while the edges of others were less sharp than drawn here.

Barnard took this pair of pictures three hours apart on the night of September 30, 1908, with Yerkes Observatory's 6-inch Bruce telescope. The start of the separation of the tail from the head, shown on page 74, is clearly evident.

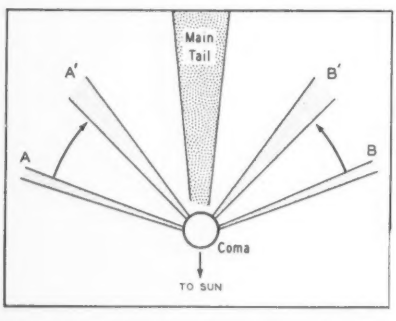
ized carbon monoxide (CO^+). The ratio of forces in this case depends on the molecule's ability to absorb solar radiation. According to W. Baade and W. Pauli, and K. Wurm, the value of R for CO^+ is approximately five. While other molecules may have somewhat larger or smaller ratios, it is improbable that any cometary molecules are driven away by solar radiation with forces 10 or 100 times larger than the gravitational attraction of the sun.

For Comet Morehouse, the acceleration of gases in the tail has been determined by several astronomers from the velocities of various condensations, sharp gaps, and other features. Thus, A. Orloff found the ratio of forces to be about 60; S. V. Orloff obtained values between 70 and 160; S. Pokrovsky's result was near 105; and N. T. Bobrovnikoff suggested ratios between 90 and 150. We thus have firm evidence that the observed values can be much larger than that from the Baade-Pauli-Wurm formula for CO^+.

Until 1952 this discrepancy between theory and observation was attributed to increased density of the radiation striking a molecule. If, for some reason, the sun's energy output were many times greater than that of a black body, in those frequencies that the molecule could absorb most efficiently, then the ratio of radiation pressure to gravitation could be larger than otherwise predicted. However, we know now that this is not the explanation.

A hypothesis proposed by the German astronomer L. Biermann, at the 1952 Liége symposium on the physics of comets, marked an important step in our understanding of the processes involved. He pointed out that the clouds of solar particles, mostly protons and free electrons, that travel away from active regions on the sun, might produce a repulsion that could easily be 10 or 100 times greater than ordinary radiation pressure.

Valuable insight into the problem comes from an important discovery made as long ago as 1910 by A. Kopff of Heidelberg, from a study of Comet Morehouse. He measured the angles between certain streamers of this comet on pairs of photographs, made at Heidelberg by Wolf and at Yerkes by Barnard, on October 3rd and November 16, 1908. Because of the longitude difference between the two observatories, each Yerkes photograph was taken about seven hours later than the corresponding Heidelberg one, but on both dates the same streamers could be identified with certainty. Kopff found that every streamer was turning around the nucleus, *in the comet's orbital plane*, in such a manner as to approach the prolongation of the line from the sun through the nucleus. This is shown schematically in the diagrams.

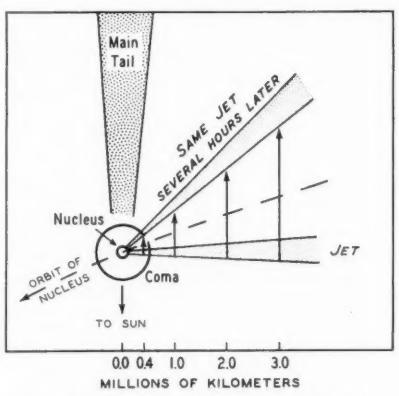


The rotation of tail streamers found by A. Kopff is indicated, as seen from above the orbit plane of the comet.

This turning was approximately three or four degrees per hour. Since the streamers when first noted made an angle of not more than 45 degrees with the prolongation of the radius vector, in 10 or 12 hours each ray had merged with the diffuse material of the straight, broad, main tail of the comet. This explains why it is usually impossible to identify the same streamers on photographs taken on successive nights. As the older rays merge into the main tail, new ones are formed that are at first quite short but become more elongated as they rotate toward the main tail.

In his paper of 1910, Kopff concluded that each streamer is at first a narrow jet of gas expelled from the comet's nucleus, usually at approximately right angles to the line toward the sun. The initial velocity of the jet is small — a few kilometers per second at most.

Then, argued Kopff, the jet becomes



To produce the observed rotation, the repulsive force must be greater at larger distances from the comet's head.

subjected to a repulsive force acting away from the sun, a force small for the jet particles near the comet nucleus but increasing for more distant particles. Just how the pattern appears to an observer depends on his location with respect to the plane of the comet orbit. The pattern as it would be seen looking perpendicularly downward toward the orbital plane is sketched on the facing page.

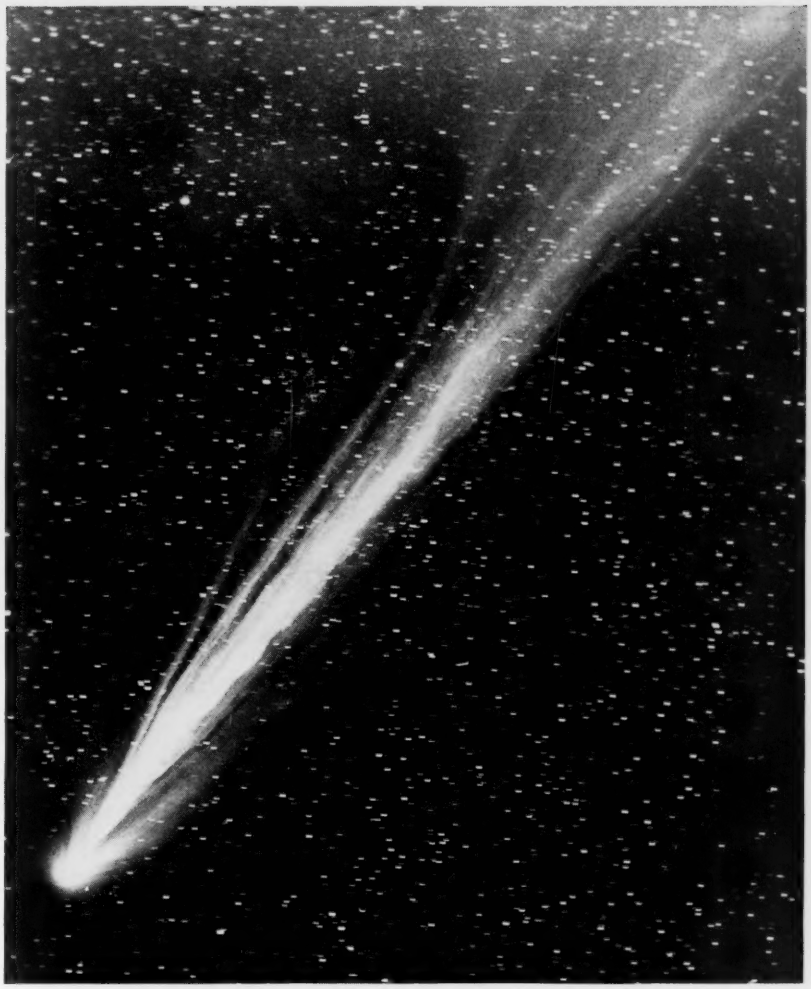
The lengths of the arrows at 0.4, 1, 2, and 3 million kilometers imply force ratios of 400, 1,000, 2,000, and 3,000, respectively. Thus, according to Kopff, the jet particles suffer very much larger accelerations than do the condensations in the main tail for which, as we have seen, the force ratio is of the order of 100.

An investigation published by Stumpff in the *Zeitschrift für Astrophysik* a few months ago seems to have answered two questions raised by Kopff: Why are the accelerations in the jet larger than in the main tail, and why do they grow with increasing distance from the nucleus?

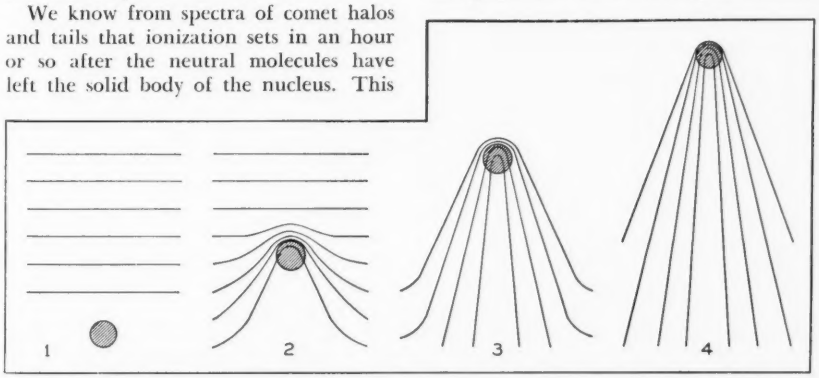
Stumpff began by measuring two Heidelberg photographs of Comet Morehouse obtained on October 29, 1908, 10-minute exposures separated by about half an hour. The measurements fully confirm Kopff's earlier conclusions. Inside the main tail, the condensations have relatively small accelerations, usually well under 100 times that of gravitation. But in the streamers the force ratio gradually increases with distance from the central axis of the tail, reaching values of the order of 1,000 or even 10,000 at the tips of the streamers.

These results are interpreted by Stumpff in the following manner. As sunlight heats the comet's nucleus, neutral molecules evaporate with velocities of about one kilometer per second, and move in a wide curve, mostly toward the sun. As long as these molecules remain neutral, they are not appreciably repelled by the clouds of solar protons and electrons, nor do they tend to interact with these solar particles, a point shown by Biermann in 1952. Also, radiation pressure has only a small effect.

We know from spectra of comet halos and tails that ionization sets in an hour or so after the neutral molecules have left the solid body of the nucleus. This ionization is not due to the far-ultraviolet radiation of the sun, for it would take many days for this to ionize fully cometary molecules of CO_2 and N_2. Instead, Biermann suggested that the mechanism responsible for the ionization is what German physicists call *Umladung* — transfer of an electron from a neutral cometary molecule to a solar proton, rendering the latter a neutral hydrogen atom, which eventually becomes ionized again.



By November 15, 1908, the tail of Comet Morehouse consisted mainly of streamers, as shown here. These changed too rapidly to be recognized on successive nights. Photograph by E. E. Barnard.



The lines indicate the magnetic field in a cloud of charged particles from the sun. H. Alfven made drawings like these (adapted from "Handbuch der Physik") to show stages in the encounter of a comet head (shaded circle) with such a cloud, warping and dragging the lines of force. Alfven believes changes in comet tails are primarily magnetic in nature.

This process works rapidly enough to explain the fast ionization of the cometary gases. It would not occur if there were no clouds of solar particles. But Biermann believes that even at times of low solar activity there are about 1,000 protons per cubic centimeter in interplanetary space, at the earth's distance from the sun. The number can be raised to 10,000 or even 100,000 by violent solar eruptions.

As soon as the cometary halo becomes largely ionized, its molecules interact strongly with the charged solar particles, which are moving as fast as 1,000 kilometers per second. The cometary molecules are repelled, and driven back into the coma. Something like a pressure front appears between the expanding un-ionized gases and the returning ionized material. A compression of the magnetic lines of force in the solar cloud may even occur.

At this stage, the formation of jetlike streamers at right angles to the direction

On October 2, 1908, after Comet Morehouse shed its tail, as shown in the three views on page 74, the head developed these broad, fan-shaped streamers. Later the new tail brightened.

toward the sun seems reasonable. The streamers often appear so narrow and threadlike that they are almost certainly held together by magnetic forces. Consisting of ionized molecules, the streamers are accelerated by the pressure of the solar corpuscles. The molecules far from the nucleus feel the full effect of this driving force; those deep inside the coma are partly shielded by it, and move more slowly.

Qualitatively, at least, I believe that Stumpff's work has given us an excellent integration of the early ideas of Kopff and the more recent thinking of Biermann. But when I look at the extraordinary threadlike appearance of the streamers on many photographs, for example in the November 16th view of Comet Morehouse, I suspect that the magnetic effects are not yet fully appreciated. Probably the alternative theory of H. Alfvén (summarized by Wurm in *Handbuch der Physik, 52,* 509, 1959) should be explored in greater detail. His theory, though also based on the action of clouds of solar corpuscles, requires much lower cloud densities than Biermann considered.

Amateur Astronomers

THIS MONTH'S PROGRAMS

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. December 11, Dr. W. A. Hiltner, Yerkes Observatory, "Telescopic Image Intensification."

Also 8 p.m., Strosacker auditorium. December 30, Dr. Fred Hoyle, St. John's College, Cambridge University, "Astronomical Radio Sources."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Dallas Health and Science Museum Planetarium. December 28, Ted F. Gangl, "Our Servant — The Atom."

Miami, Fla.: Southern Cross Astronomical Society, 8:15 p.m., Museum of Science and Natural History. December 21, Vincent Gabianelli, "A Planetarium Show."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. December 2, Dr. Robert Jastrow, National Aeronautics and Space Administration, "The Coming Exploration of the Moon."

New York, N. Y.: Junior Astronomy Club, 8 p.m., Waverly building, New York University. December 18, Dr. Kenneth L. Franklin, American Museum-Hayden Planetarium, "The Planet Jupiter."

Philadelphia, Pa.: Rittenhouse Astronomical Society, 8 p.m., Franklin Institute. December 11, Dr. Raymond H. Wilson, Jr., Naval Research Laboratory, "Magnetic Evolution of Space Vehicles and Other Celestial Bodies."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. December 5, Dr. Charlotte M. Sitterly, National Bureau of Standards, "The Ultraviolet Spectrum of the Sun."

OHIO TURNPIKE AMATEURS

Originally our meeting on September 19th at the University of Toledo was planned only for the Ohio Turnpike Amateur Astronomers, but since we felt we had a very attractive program, other clubs in central Ohio and southern Michigan were invited. A total of 135 amateurs registered.

Two speakers from the University of Michigan were featured. Dr. Hazel M. Losh gave a talk on southern skies and the Magellanic Clouds. Dr. Dean B. McLaughlin told of his studies of Mars, from which he concluded that the planet's markings are mostly of volcanic origin, and that prevailing winds may be responsible for the definite pattern generally seen on the planet.

A highlight of the meeting was a U. S. Army exhibit tracing the history of rocketry from A.D. 1232 to the present. There were scale models of many rockets, including the Redstone and Jupiter missiles.

C. E. SHINKLE
9361 Lewis Ave.
Temperance, Mich.

NORTHEAST CONVENTION

Although bad weather prevented viewing the total solar eclipse on October 2nd, the 110 registrants of the Northeast Region of the Astronomical League had a full program for their meeting in Boston. There were sessions on observing and instrumentation, the convention banquet which included a talk on tektites by Dr. Gerald S. Hawkins of Boston University, and a field trip to Harvard Observatory's Agassiz station.

Regional officers for the coming year are Mrs. Helen Velardi, New Haven, Conn., chairman; Edgar Everhart, Mansfield Center, Conn., vice-chairman; John E. Welch, Springfield, Mass., treasurer; William Miller, Mountainside, N. J., secretary; and Clarence Johnson, Schenectady, N. Y., regional representative.

The region will meet in New York City on April 30, 1960, with the Junior Astronomy Club as host.

HUNTSVILLE, ALABAMA

A booklet describing its history and activities has been published by the Rocket City Astronomical Association. Highlighted is the story of the society's observatory building (SKY AND TELESCOPE, March, 1957, page 225). The club's address is P. O. Box 620, Huntsville, Ala.

AAVSO MEETS AT NAHANT

The 48th annual fall meeting of the American Association of Variable Star Observers was held at Nahant, Massachusetts, October 1-4. Although the time and place had been selected to coincide with the total eclipse of the sun on October 2nd, rain prevented its observation.

Besides sessions for papers on variable stars and solar observing, the four-day gathering included a tour of Harvard Observatory's Agassiz station, inspecting the 60-foot radio telescope and the 61-inch reflector. Ralph N. Buckstaff, Oshkosh, Wisconsin, was re-elected president for the coming year, and Mrs. Margaret W. Mayall continues as director.

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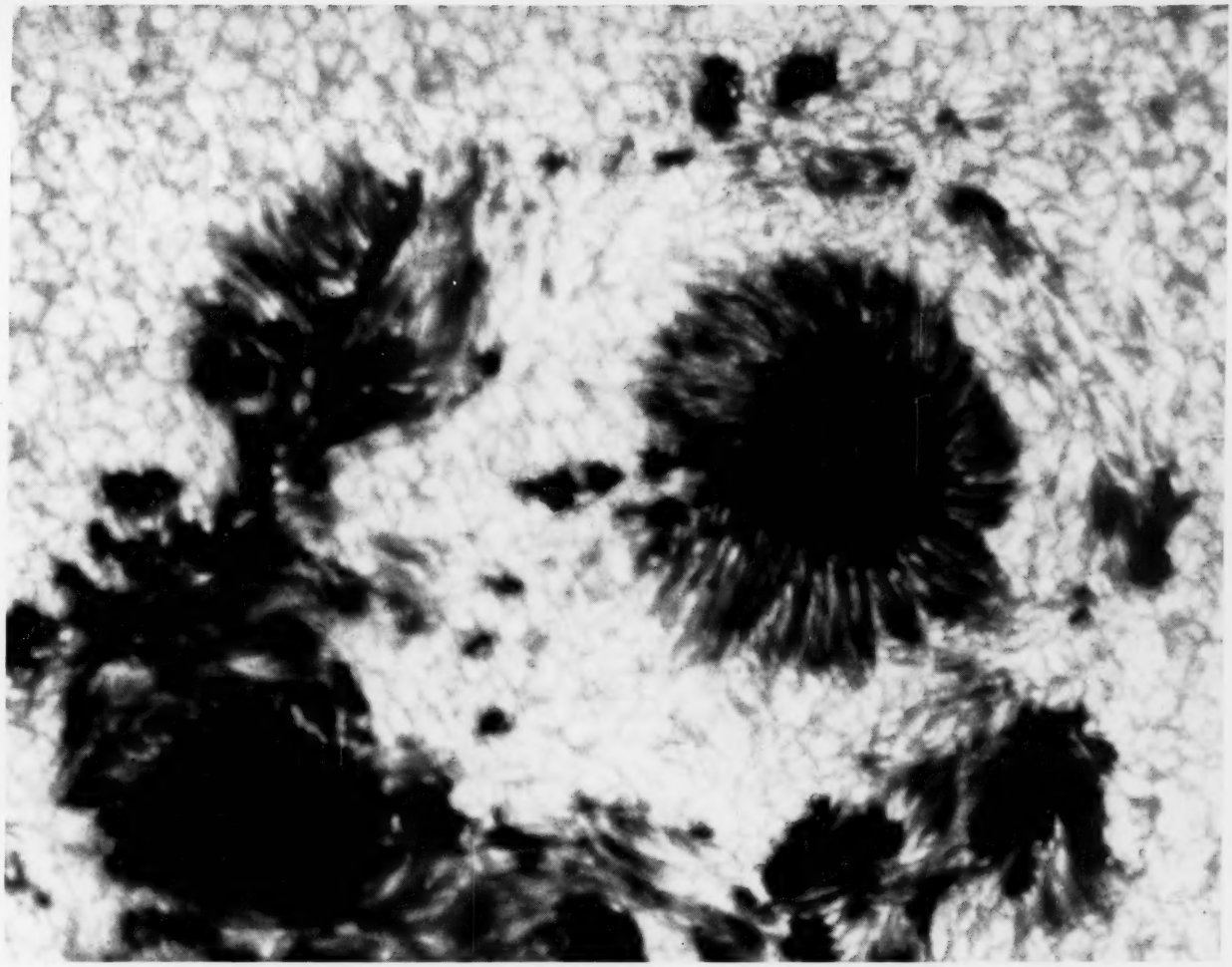


Remarkable structural details are seen in the sun's surface and sunspot penumbrae in this August 17th picture. This solar region was associated with a terrestrial magnetic storm the previous day. Project Stratoscope photograph.

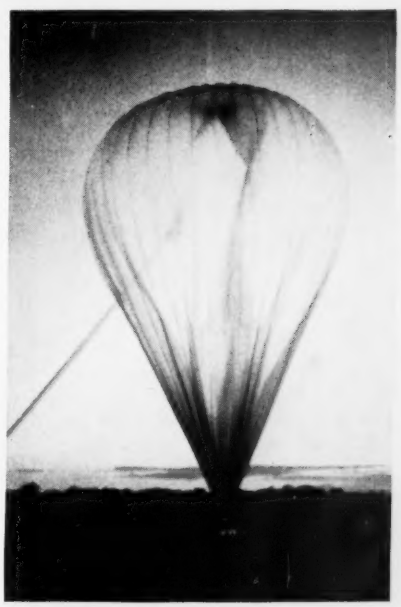
Project Stratoscope Obtains Finest Pictures of the Sun

SOLAR PHOTOGRAPHS of unsurpassed quality were obtained during the second series of Project Stratoscope balloon flights, on July 11th and August 17th this year. Selected regions of the sun were recorded by means of a television camera and remote-control mechanism, providing even better definition than in the first series (SKY AND TELESCOPE, January, 1958, page 112).

As the huge General Mills high-altitude balloon drifted at an altitude of 80,000 feet, Dr. Martin Schwarzschild, Princeton University astronomer and technical director of the project, observed the televised solar image in an instrument-carrying van on the ground. He was able to direct the telescope to areas on the sun of greatest interest and to focus the image on the film while the pictures were being taken. He called the 400 photographs obtained on August 17th the "sharpest pictures ever taken of sunspots."

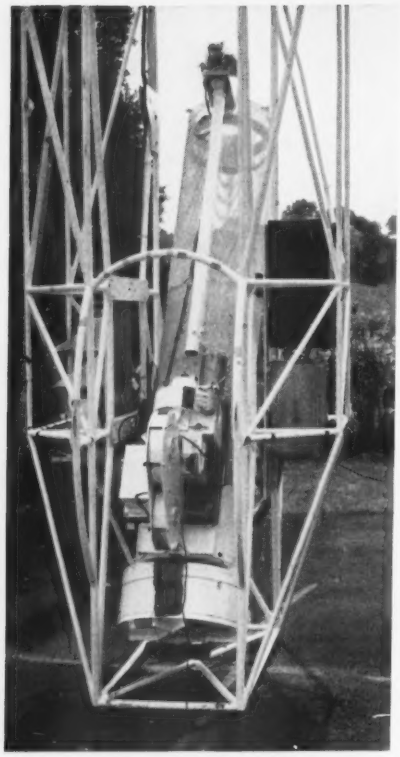
Although the same 12-inch quartz-mirror telescope was used in 1959 and in the 1957 flights, the auxiliary equipment was considerably improved. To overcome motor vibration from a rotating secondary mirror, a tiny (1-by-1½-millimeter) speculum metal mirror was embedded in a sheet of copper, the latter conducting away the heat of the primary image. The little mirror deflected a small part of the sun's image to a transfer lens and on to the camera, where a beam-splitter diverted one-fifth of the energy to the vidicon tube of the television system.

Upon command from the ground, the small transfer lens could be moved axially, refocusing the image as the main mirror was affected by the heat of the sun. In 1957, when no television system or



The Stratoscope balloon, with a capacity of one million cubic feet, is inflated for the flight of July 11th. From a Kodachrome by Harold J. Watson.

NEWS NOTES



The solar camera and its film magazine are carried on the telescope tube, with the television camera at the left. To the right is the transmitter, while above it (black box) are the telemetering equipment and the remote-control command system.

ground control were used, the transfer lens had to traverse the focusing range continuously and automatically, and only one exposure in 20 was obtained in perfect focus.

Although the July 11th flight resulted in 8,000 photographs, only a fair number were of good quality. Dust and vibrations of the optical parts caused by motors produced objectionable film defects. But the August flight was remarkably successful, foreshadowing many kinds of future observations in which the astronomer is on the ground while his equipment is taken above the atmosphere to where observing conditions are nearly perfect.

The August 17th launching occurred at 5:59 a.m. Central standard time, and the instrument package was carried 127 air miles in various directions during the next seven hours, reaching a maximum altitude of 80,000 feet, finally coming to earth near Cannon Falls, Minnesota, only 45 miles from the launching site at Brighton.

Project Stratoscope is sponsored jointly by the Office of Naval Research and the National Science Foundation. The television system was developed by Radio Corp. of America, and the telescope-camera equipment by Perkin-Elmer Corp., which is also designing the much larger 36-inch balloon telescope for Project Stratoscope II.

16TH-CENTURY PLANETARY POSITION PREDICTOR

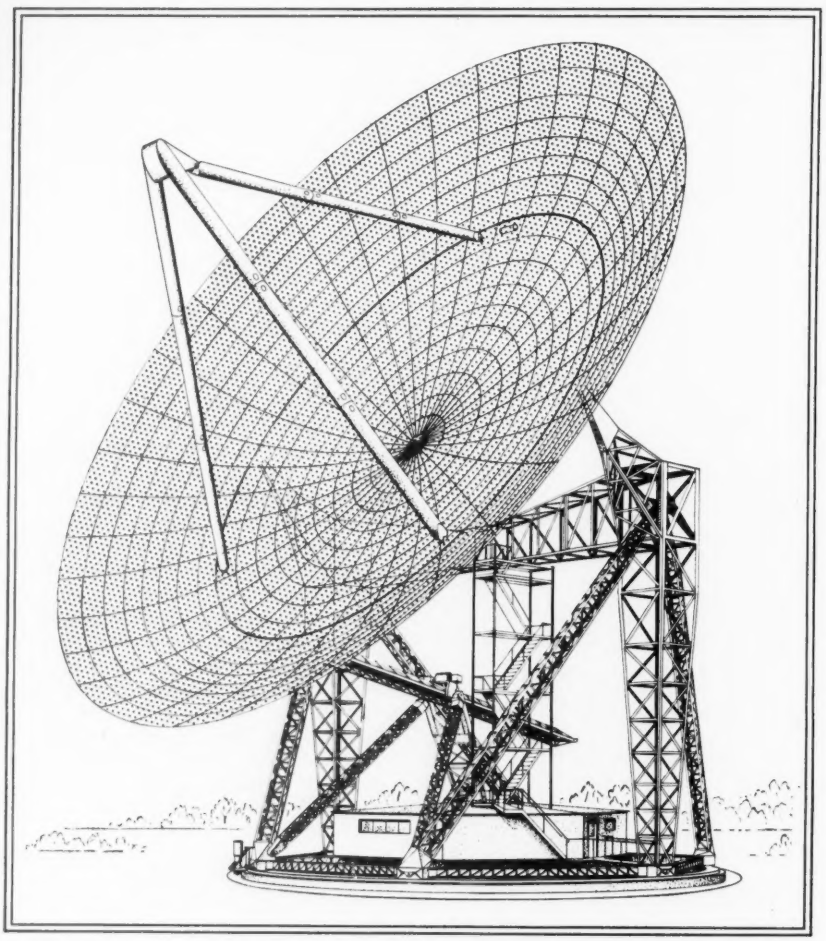
The German astronomer Peter Apian (1495-1552) was the author of an unusual astronomical work entitled *Astronomicum Caesareum* and published in Bavaria in 1540, three years before Copernicus died. Frederick A. Stebbins, of Longmeadow, Massachusetts, recently examined a copy of this "magnificent volume" in the Maitland collection in the rare-book vault of the New York Public Library. He describes Apian's work in the October, 1959, *Journal* of the Royal Astronomical Society of Canada.

The book contains many large colored diagrams with movable parts attached to the pages, these devices designed to calculate the positions of the planets, the sun, and the moon, for the years from 7000 B.C. to A.D. 7000. One diagram, $11\frac{1}{2}$ inches across, is for predicting the longitude of Jupiter. It consists of an ecliptic circle printed on the page, with three large and two small disks of heavy paper that turn on three different centers.

How well does this device work? Mr. Stebbins used it to calculate the longitude of Jupiter for 13 dates in 1959-60, comparing them with data from the *American Ephemeris*. The average error was less than two degrees, remarkably small when it is considered that Apian's observations were made before the invention of telescopic sights, that he used the Ptolemaic model of the solar system, and that four centuries have elapsed in which errors could accumulate.

142-FOOT RADAR TELESCOPE FOR STANFORD UNIVERSITY

More accurate measurements of cosmic distances, surface explorations of the moon and planets by radar, studies of Venus' rotation, and the ionization and distribution of gases around the sun and in interplanetary space, are among the projects planned for a giant 142-foot paraboloidal radar telescope to be built at Stan-



The trustees of Stanford University broke with tradition by approving plans to erect this giant radar telescope on the scenic foothills behind the campus at Palo Alto, California. As high as a 15-story building, the giant dish will have a diameter two feet greater than the 140-foot radio telescope now being constructed at the National Radio Astronomy Observatory in West Virginia.

IN THE CURRENT JOURNALS

THE EARTH IN THE SUN'S ATMOSPHERE, by Sydney Chapman, *Scientific American*, October, 1959. "The sun's atmosphere can be said to end only at a distance where its density has fallen to that of the gas in interstellar space. In the vicinity of the earth the solar atmosphere may have a density of about 9,000 protons (hydrogen nuclei) and 9,000 electrons per cubic inch. This is an extremely thin gas, but it is nonetheless many times denser than the gas in interstellar space."

ford University within a year. The antenna will cost an estimated $250,000 and its transmitter more than a million dollars. It will be the most powerful transmitter ever built to operate in the range of 20 to 60 megacycles. The antenna is designed for frequencies from 20 to 2,000 megacycles. The project has the support of the Air Force Cambridge Research Center.

DECEMBER MEETINGS

The 104th meeting of the American Astronomical Society will be held at the Case Institute of Technology, Cleveland, Ohio, December 27-30. The program will feature a conference on astronomical observations from above the earth's atmosphere, and the Warner prize lecture by E. Margaret and Geoffrey R. Burbidge of Yerkes Observatory.

On December 26th at the Morrison Hotel in Chicago, Illinois, Section D (Astronomy) of the American Association for the Advancement of Science will have two symposia. One will deal with the moon and solar system; the other, on photoelectric techniques for amateurs, will be jointly sponsored by the Astronomical League. Amateur astronomers are invited to attend.

PECULIAR VARIABLE STAR

A faint blue star in the constellation Sagitta has steadily been brightening for the past 70 years, according to Gerold Richter, of Sonneberg Observatory in East Germany. The variability of this star, 377.1943 Sagittae, had first been noted 16 years ago, by Cuno Hoffmeister at the same observatory.

In 1890 the star was magnitude 13.7, and it had attained 10.3 by 1959. Dr. Richter's study, based on nearly a thousand photographic and visual observations, shows that small irregular waves of about a few months duration are superimposed on the progressive brightening.

The spectrum of the variable is also unusual. N. B. Richter's spectrographic observations at Sonneberg show that 377.1943 Sagittae is a *B* star with several Balmer lines of hydrogen in emission, together with bright lines characteristic of gaseous nebulae. The spectral lines vary from night to night in intensity, width, and number of components — indicating very rapid changes in the extensive gaseous envelope surrounding the star.

Dr. Richter points out that this variable is a more extreme counterpart of the star AG Pegasi, discussed by P. W. Merrill on page 490 of SKY AND TELESCOPE for July, 1959.

AURORAL WALL OF LIGHT

The great aurora of September 3-4, 1959, reported on page 14 of last month's issue, is discussed by C. W. Gartlein, Cornell University, in *News Letter* 26 of the IGY Auroral Data Center at Ithaca, New York. All the reports had not been processed (by October 23rd), but Dr. Gartlein writes:

"This outburst occurred at 11:45 Eastern daylight time or 3:45 Universal time, and was simultaneous all across the country, which was relatively free from clouds. . . . As it got bright the outermost arc moved south at about the speed of sound, and formed rays which were at least 160 miles high at the top. We don't often put the aurora in ordinary figures, partly because it is not often that we are so sure that everyone is looking at the same thing. But for a while, on the night of September 3/4, there was a wall of light as long as the United States is wide, over 100 miles tall, with its bottom 60 miles from the ground, moving south at 700 miles an hour. The aurora is always so far away that we seldom appreciate what a big commotion is really going on."

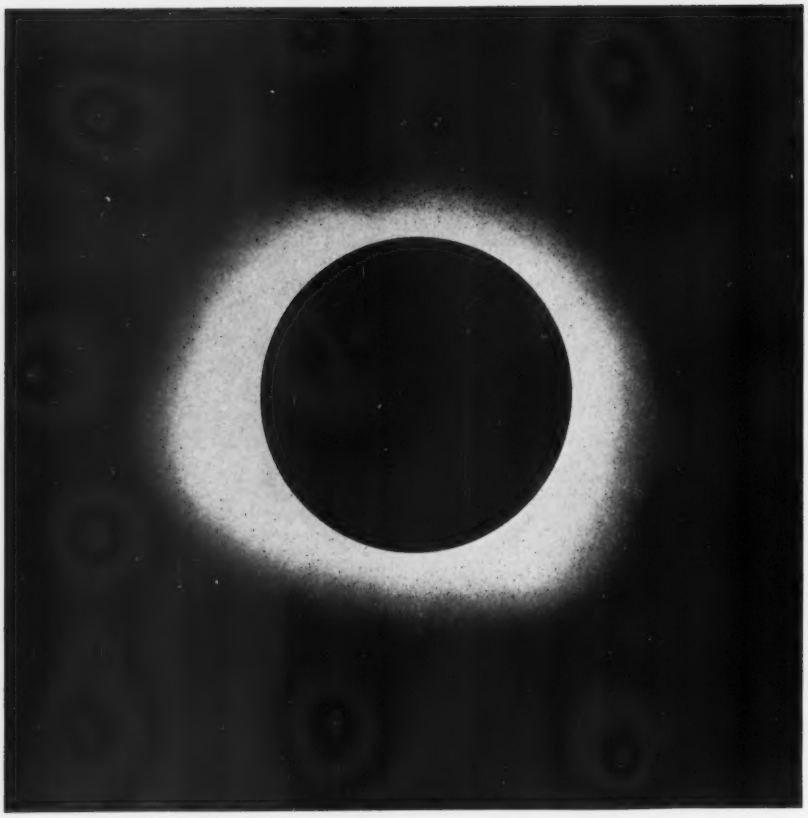
NEW DIRECTOR FOR DEARBORN

J. Allen Hynek has been named chairman of the department of astronomy at Northwestern University and director of Dearborn Observatory. Dr. Hynek has been granted a year's leave of absence to complete his work at the Smithsonian Astrophysical Observatory, and will take up his post at Evanston, Illinois, in September, 1960. Karl G. Henize, formerly on the Smithsonian staff, has been appointed associate professor of astronomy and assistant to Dr. Hynek.

MOON-VENUS CONJUNCTION

On the morning of October 28th, the moon passed near Venus for United States observers, while in South America an occultation of the planet occurred. This picture was obtained by Ken Cobean at Caprock, New Mexico, 40 minutes before sunrise there, while Peter A. Leavens took a corresponding view at Short Beach, New York. In a 35-minute telephone call to New Mexico, he had given Mr. Cobean suggestions for their co-operative enterprise.

The latter used a one-second exposure on Royal Pan film, at f/6, recording earthshine on the moon's dark side and the 1,610-foot transmitter tower of Roswell's KSWS-TV, one of the world's tallest man-made structures.



The sun at the total eclipse of October 2, 1959, photographed by the Swiss expedition in western Africa. The sun's axis extends obliquely from upper right (south) to lower left (north). The northern corona is more developed than the southern, and its general appearance is characteristic of an intermediate stage in the 11-year solar cycle.

Total Eclipse at El Aaiun

M. WALDMEIER

Swiss Federal Observatory, Zurich

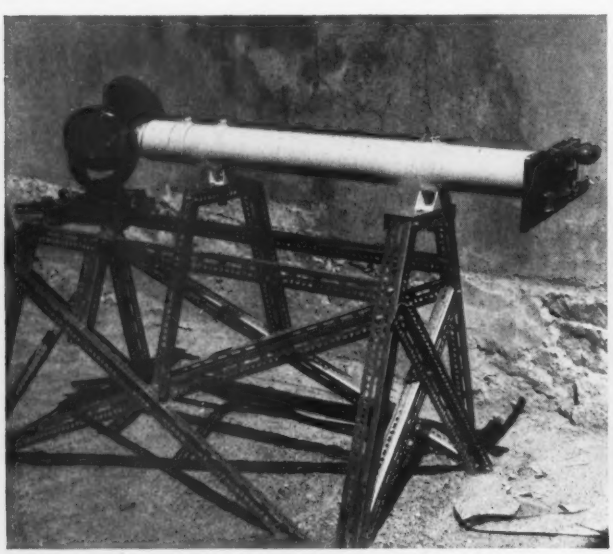
FOR the total solar eclipse on October 2, 1959, the Swiss Federal Observatory sent an expedition to El Aaiun, West Africa, in the Spanish Sahara. This was my fifth eclipse expedition since 1952, and I was accompanied by Fritz Siegrist.

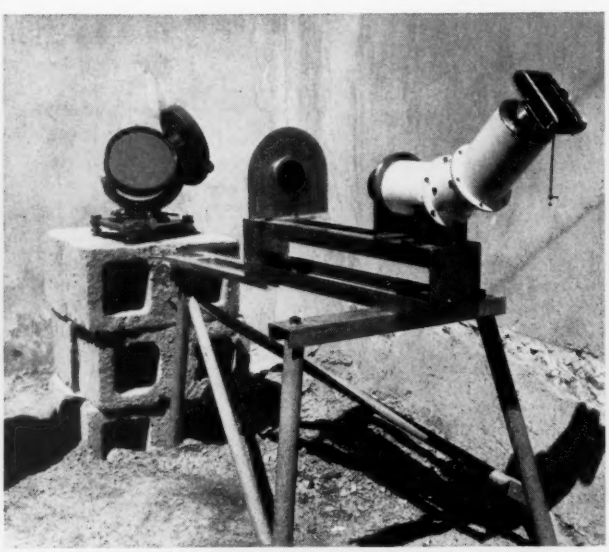
Our instruments were small ones, to permit transport by commercial airliners. We used an f/20 horizontal camera of 2.4-inch aperture to record the distribution of brightness in the corona. From photometric measurements of the 12 plates taken with this camera, the electron density in the corona will be deduced.

This data will be needed to interpret the exposures made with a fast one-prism spectrograph. The purpose of the spectrographic program was to record the coronal emission lines — especially the one at 5303 angstroms — to the greatest possible distance from the sun's limb. The manner in which the intensities of these bright lines decrease with distance from the sun will make it possible to decide whether the lines are excited by electron collisions or by solar radiation. Two sets of spectrograms were obtained, one with the slit along the solar equator (reproduced opposite), the other with the slit along the axis of the sun, from north to south.

Two short-focus cameras were used for polarization measurements and photometry of the outer corona. In addition, the eclipse was filmed in black-and-white and in color. The Kodachrome films, taken at eight frames per second with an f/4 lens of 5.9-inch focus, show very nicely the inner corona and the prominences.

At the site of our Swiss party, thin





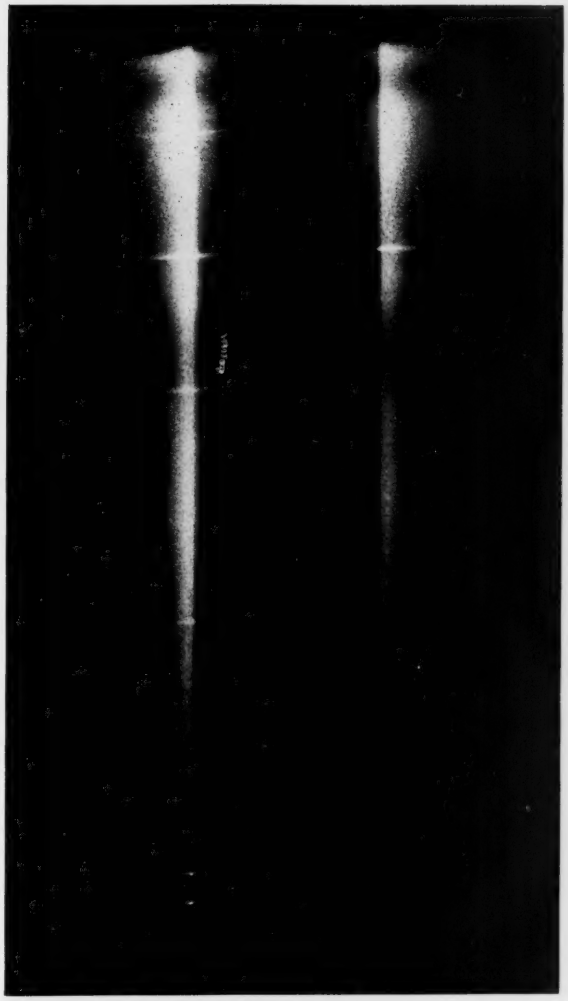
The Swiss expedition carried simple but effective equipment easily set up under difficult field conditions. Both the 2.4-inch f/20 camera (left) and the one-prism spectrograph were placed horizontally and fed by coelostat mirrors. All illustrations with this article were supplied by the Swiss Federal Observatory.

Natives of El Aaiun waiting for the total eclipse to take place.

cirrus clouds were passing in front of the sun during totality. No trace of these clouds is shown on the shorter exposures, but some of the longer ones are badly fogged by scattered light. Therefore, our reliable results will probably be restricted to the inner corona.

EDITOR'S NOTE: Also at El Aaiun was an expedition from the University of Madrid, headed by Jose M. Torroja. However, the sky was covered by clouds, and Dr. Torroja reports that while his photographic observing program was carried out as planned, probably few scientifically useful results were obtained. The University of Madrid scientists also made photometric measurements of the corona from a military plane flying 18,000 feet above the desert.

The Canary Islands off the coast of West Africa were within the path of totality, and American, British, Dutch, and Spanish parties went there. But generally weather conditions in the Canaries were also unfavorable, although it was clear at Tenerife.



The spectrum of the inner corona along the solar equator, showing the continuum at both limbs as well as the strong green emission line at 5303 angstroms (1½ inches from the top of the picture). On the left side a prominence produced the strong emissions (top to bottom) at 5876 angstroms (helium), 4861, 4340, and 4102 (hydrogen), and the H and K lines of ionized calcium, in which the prominence itself may be seen.

The corona, as photographed with a camera of 14-inch focal length, the picture above being taken about 10 seconds before third contact to record the chromosphere, prominences, and the inner corona. A longer exposure is at the right.

Predicting and Observing Lunar Occultations

FLORA MCBAIN SADLER, *H. M. Nautical Almanac Office, Royal Greenwich Observatory*

AS THE MOON moves in its orbit around the earth, it occasionally passes between a star and a terrestrial observer, and the star is said to be occulted. Observing an occultation consists of accurately determining the time of disappearance or reappearance of the star at the limb (edge) of the moon. An individual observation of this kind gives a relation between the positions of the star, the moon's limb, and the observer.

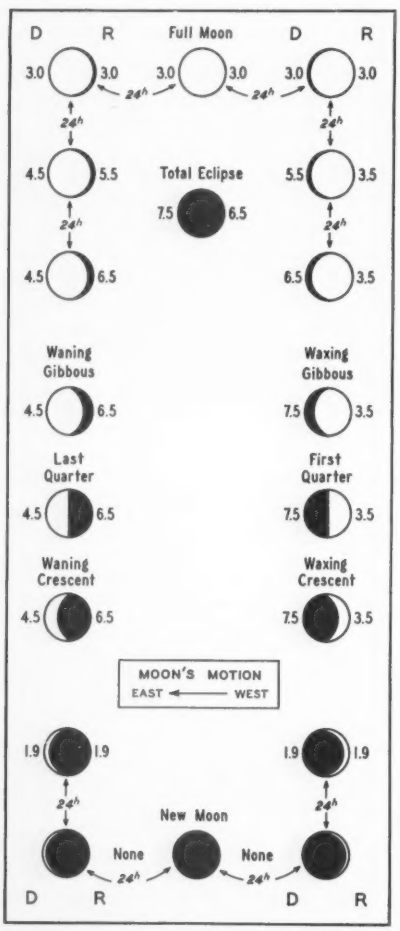
The positions of the stars and the geographical co-ordinates of the observers must be known with sufficient accuracy for the statistical analysis of a series of occultation observations. From this can be determined the distance, size, and motion of the moon in its orbit. Timing an occultation is a relatively simple observation which can be made with a telescope of moderate aperture, and amateur astronomers can contribute to astronomy by making regular observations of these events.

The observation of occultations in the past was chiefly responsible for the discovery that the rotation of the earth on its axis is not uniform. This led to the necessity for the concept of Ephemeris time, which is independent of the earth's rotation and is being used in the fundamental ephemerides of the sun, moon, and planets from 1960 onward. The difference between Universal time, which does depend on the rotation, and Ephemeris time can only be obtained subsequently from observations. The analysis of occultation observations will form a valuable means of determining this difference, which can also be evaluated from observations with the Markowitz moon camera and with transit circles.

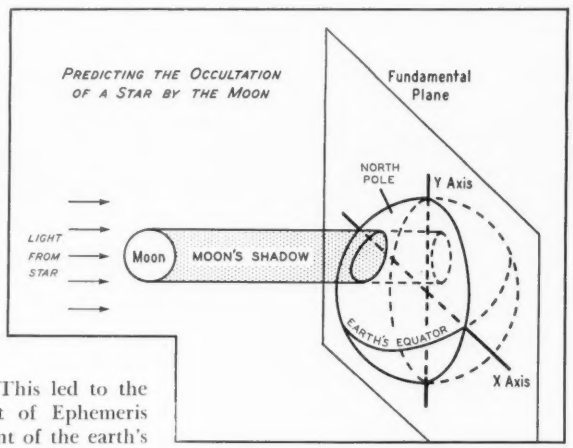
In the future, the value of these results will be enhanced by the application of corrections for irregularities on the moon's limb, taken from the charts now in the course of publication by C. B. Watts at the U. S. Naval Observatory. In this way, it will be possible to improve the numerical values of quantities describing the moon and its orbit. For example, we should like to determine the moon's diameter more accurately; this would be possible if occultation observers made more timings of reappearances, as well as of disappearances.

World-wide predictions of occultations have been undertaken in England since 1937 by H. M. Nautical Almanac Office, and by international agreement since 1943 the office has been responsible for the collection, reduction, and discussion of the observations. At present, predictions are made for about 80 stations, in the hope that all suitable occultations will be observed whenever possible. The information supplied consists of an approximate time, and the position angle of the point on the moon's limb where the star disappears or reappears.

For this year and earlier, occultation predictions were published in the *American Ephemeris* and the British *Nautical Almanac*, but these books have now been made identical and contain no material on occultations. Therefore, beginning in 1960, various other publications will carry the predictions. Those for 12 stations in North America appear in the center supplement of this issue of SKY AND TELESCOPE.



Limiting magnitudes for occultation predictions are indicated in this chart. On the right-hand side disappearances are at the dark limb; on the left at the bright one. The exception to the general rule is at a total eclipse of the moon, when predictions are given for the faintest stars in the program. The moon's motion from west to east in the sky is indicated.



The basic concept of the Besselian geometry used in predicting occultations. Light from a star passes the moon and casts a cylindrical shadow behind it. Within the area where this shadow intersects the earth's surface, the star is hidden by the moon. The fundamental plane passes through the center of the earth and is perpendicular to the axis of the moon's shadow.

CHOICE OF OCCULTATIONS

Precise star positions are needed if occultation records are to be useful, and for this reason predictions are given for the objects in the *Catalog of 3539 Zodiacal Stars for the Equinox 1950.0*, known as the *Z.C.*, which was published in *Astronomical Papers of the American Ephemeris*, Vol. 10, Part 2, 1940. To restrict predictions to those occultations for which satisfactory timings can be made, only stars of magnitude 7.5 and brighter are included, and certain further limitations are imposed.

Because they are generally difficult to observe, no predictions are given for reappearances of stars between magnitude 6.6 and 7.5. Faint stars are hard to see at the moon's bright limb, so disappear-

ances there are given only for stars of magnitude 4.5 and brighter, and reappearances for stars 3.5 and brighter. The other restrictions associated with the moon's phase are indicated in the chart.

Owing to lessened sky transparency near the horizon, the occultation event must occur at an altitude of 10 degrees or higher for a prediction to be given, except for stars of magnitude 1.9 and brighter, for which the adopted altitude limit is two degrees. Only for these same very bright stars are daylight occultations included. For others the earliest and latest times of predictions (the sunset and sunrise limits) correspond respectively to depressions of the sun below the horizon as follows:

Magnitude	*Evening*	*Morning*
2.0 to 4.5	Sunset	6°
4.6 to 5.5	3°	9°
5.6 to 7.5	6°	12°

Occultations in which the star appears to graze the moon's edge are not predicted, and the longitude and latitude coefficients **a** and **b**, which become unreliable for grazing occultations, are omitted when these conditions are approached.

For the planets, lunar occultations are also given, with the same restrictions as for the stars.

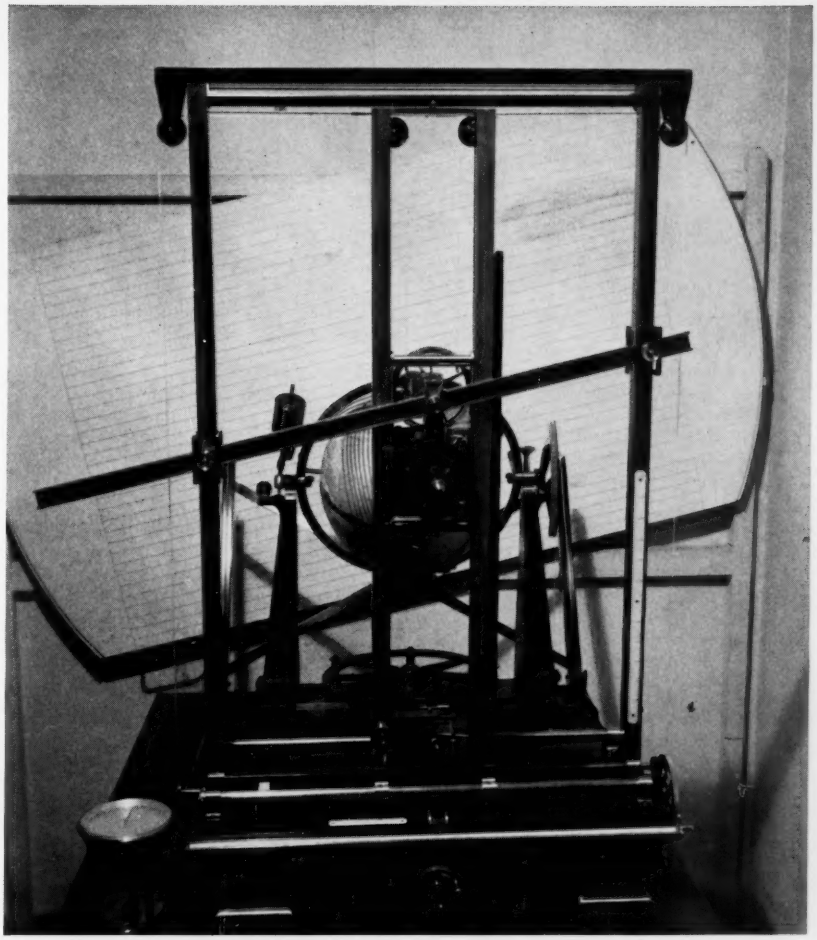
The Prediction Process

If, at any instant, the angular distance of a star from the moon's center is less than the sum of the moon's horizontal parallax and semidiameter, then the star must be occulted from some point on the earth. There are about 2,330 Z.C. stars of magnitude 7.5 or brighter for which occultations are possible, and in any one year many of them may be occulted more than once, as the moon passes 12 or 13 times around the sky along approximately the same path. The first step in preparing the predictions is selecting the probable cases, usually a year at a time. The limitations depending on the moon's limb and phase are then applied.

For the remaining stages of prediction, use is made of the geometrical idea of F. W. Bessel, called Besselian geometry. Positions are projected on a *fundamental plane,* which passes through the center of the earth and lies at right angles to the "shadow" cast by the moon in the star's light. This plane is therefore perpendicular to the line from the star through the moon's center. Owing to the great distance of the star, the moon's shadow is essentially a cylinder whose intersection with the fundamental plane is a circle of unchanging size, its diameter being equal to that of the moon. The origin of co-ordinates in the fundamental plane is the center of the earth, the *x*-axis lying along the intersection of the terrestrial equator's plane and the fundamental plane.

The Besselian elements of an occultation are calculated from the hourly values of the moon's ephemeris, specifying first the location of the center of the shadow in the fundamental plane at the time of conjunction in right ascension of the star and the moon. At conjunction, x is zero, and examination of the value of y enables elimination of many occultations that will just miss the earth.

Next, from x' and y', the hourly variations of the co-ordinates of the center of the shadow, its position on the fundamental plane can be derived easily for other times. The star's position in the sky, its Greenwich hour angle, and the Universal time of conjunction are also specified.



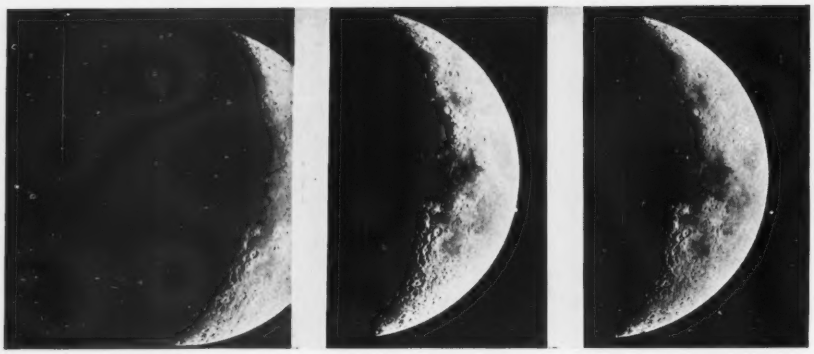
This machine is used to determine where on the earth occultations will be visible, and to provide rough times and position angles for the stations where useful observations will be possible. In the center is the 12-inch globe representing the earth, and the lines superimposed on it are sunrise and sunset limits. The light representing the moon's shadow is in front of the globe. As the handle at the lower right is turned, the earth rotates and the light source moves in synchronism with it, simulating the circumstances of the event set up on the machine. Photograph from H. M. Nautical Almanac Office.

The Occultation Machine

The next stage in the process is done with the occultation machine pictured here. It was designed with the double purpose of eliminating conjunctions for which predictions need not be given and of obtaining preliminary times and position angles at all stations for which predictions are necessary.

In the machine, the earth is represented by a 12-inch globe upon which an ordinary commercial map has been pasted for reference purposes only. Each station is represented accurately on the sphere by a black dot on a white disk. The globe can be rotated on its polar axis and tilted about a horizontal diameter, so that any point on it can be presented to the star. The moon-star-shadow system is represented by a cylindrical beam of light, obtained from a lens diaphragmed down to a diameter in the same ratio to that of the globe as the moon's diameter is to the earth's. At any moment a star is occulted at all places within the area formed by the intersection of this cylinder of light with the earth's surface. The occultation is either just beginning or just ending at places on the edge of the beam.

The lens, with its source of light, is mounted in a carriage between two uprights which allow it to slide freely in a



These Yerkes Observatory photographs record the progress of a lunar occultation of 1st-magnitude Aldebaran. The first shows the star about to be covered by the moon's dark limb; the second is immediately after emersion at the bright limb; and the third was taken 1⅔ minutes after the star's reappearance. A similar event will be visible this year on December 13th, near full moon, for many West Coast observers, as explained on page 130 of this issue.

vertical direction, while at the same time a crossbar fixed to the system compels it to follow the direction of the moon's motion. The initial alignment of the machine is for the time of conjunction, and consists only of setting the Besselian elements on the appropriate scales. The turning of a single handle (bottom right in the picture) causes the shadow cylinder to move and the earth globe to rotate in synchronism with it, so the device presents an accurate picture of the progress of the phenomenon.

The driving mechanism is connected to a clock face (lower left in picture) which reads zero at the time of conjunction and indicates the difference in time before or after conjunction as the handle is turned. Thus, the operator can watch the path of the shadow on the earth globe, reading off the times of disappearances and reappearances, and the corresponding position angles, for all stations in the path.

At this stage it is easy to eliminate conjunctions giving rise to occultations visible only from the polar regions of the earth. An adjustable grid is used to represent the different sunrise and sunset limits, and the operator also notes the events that will occur close to the horizon or be near grazes, but these limits are difficult to judge at the machine without long experience. The final decision for inclusion or exclusion of such a prediction can only be made after the accurate calculation has been done.

The final part of prediction consists in correcting the times given by the machine, which are usually accurate to within two minutes. At the moment of disappearance, the line of sight to the star is tangent to the moon's limb, or, in terms of Besselian geometry, the projection of the observer's location upon the fundamental plane should fall on the circle that is the moon's projection. This condition will not generally be exactly satisfied by the occultation machine's times, so the necessary corrections are calculated numerically.

The longitude and latitude coefficients, **a** and **b**, are calculated at the same time. They are the rates of change of time of the occultation with position, and enable observers within 200 or 300 miles of a standard station to derive their own predictions. The map on the first page of the occultation supplement shows the approximate areas that are covered by these quantities for the 12 stations in North America. As already mentioned, **a** and **b** quantities are not given for grazing occultations.

Reporting Observations

The work involved in the world-wide prediction of occultations is quite considerable and may be taken as an indication of the importance attached to these observations. Besselian elements are calculated each year for something like 3,000 conjunctions, about half of which are rejected after the examination by the occultation machine. The final list includes between 7,000 and 8,000 predictions, but a large proportion of these are wasted by bad weather conditions. At present about 1,500 observations are reported each year, but this number would be doubled if potential observers realized the need for occultation timings. It is requested that lists of occultation timings be sent to H. M. Nautical Almanac Office, Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, Sussex, England, not more than six months after the end of the observing year.

Each list should include the geographical latitude and longitude of the telescope to the nearest second of arc (100 feet) and the height above sea level. In the United States this information can be obtained from the large-scale topographical survey maps published by the Department of the Interior, at a price of 30 cents a sheet. For locations east of the Mississippi River, write to Map Information Office, U. S. Geological Survey, GSA Bldg., Washington 25, D. C.; west of the Mississippi, to Map Information Office, U. S. Geological Survey, Denver Federal Center, Denver, Colo. In Canada, the Department of Mines and Resources, Ottawa, Ontario, can provide similar material.

For each observation there should be reported: observer's name; the star's *Z.C.* number and magnitude; whether disappearance or reappearance; date and Universal time of event. In addition, mention size and kind of telescope; eyepiece power; and any relevant remarks about the quality and conditions of observation.

The method of timekeeping should be described. American observers can conveniently obtain accurate time from the short-wave radio time signals broadcast by Station WWV. Information concerning these can be obtained from the Radio Standards Division, National Bureau of Standards, Boulder, Colo.

I should like to appeal to observers to check carefully the recording and copying of their occultation observations. Where possible, we usually compare lists of observations with predictions and with lists from neighboring stations. This often enables recording errors to be corrected, such as a wrong star designation, or a mistake of an hour in the time, before the actual reductions begin. After the reduction, we examine the observations giving inconsistent results, and in many cases find that the observer has recorded the minute wrongly. These mistakes we can correct, but many observations may be lost because the number of seconds was incorrectly written down.

Treatment of the Observations

Before a particular occultation observation can be combined with others, made at different times and places, it must be *reduced* to a more convenient form by the elimination of the place of observation. The process of reduction is very similar to that of prediction, Besselian geometry again being used, but the co-ordinates are calculated more accurately. In the predictions the purpose is to obtain times to a tenth of a minute, whereas the observations must be recorded to a tenth of a second and should be accurate to at least half a second.

In the reduction, each observation yields the excess of the apparent distance of the star from the center of the moon over the adopted lunar semidiameter, together with the position angle of the star relative to the direction of the moon's motion. A series of reduced observations can be analyzed to determine the difference between the moon's actual and tabular positions, or to determine the lunar semidiameter and other constants.

Annual discussions of occultations are published in the *Astronomical Journal*, and reprints are sent to all contributing observers. Combined lists of individual observations, together with the results of their analysis, are published at intervals of about five years in the *Annals* of the Royal Greenwich Observatory, and are distributed to participants in the program.

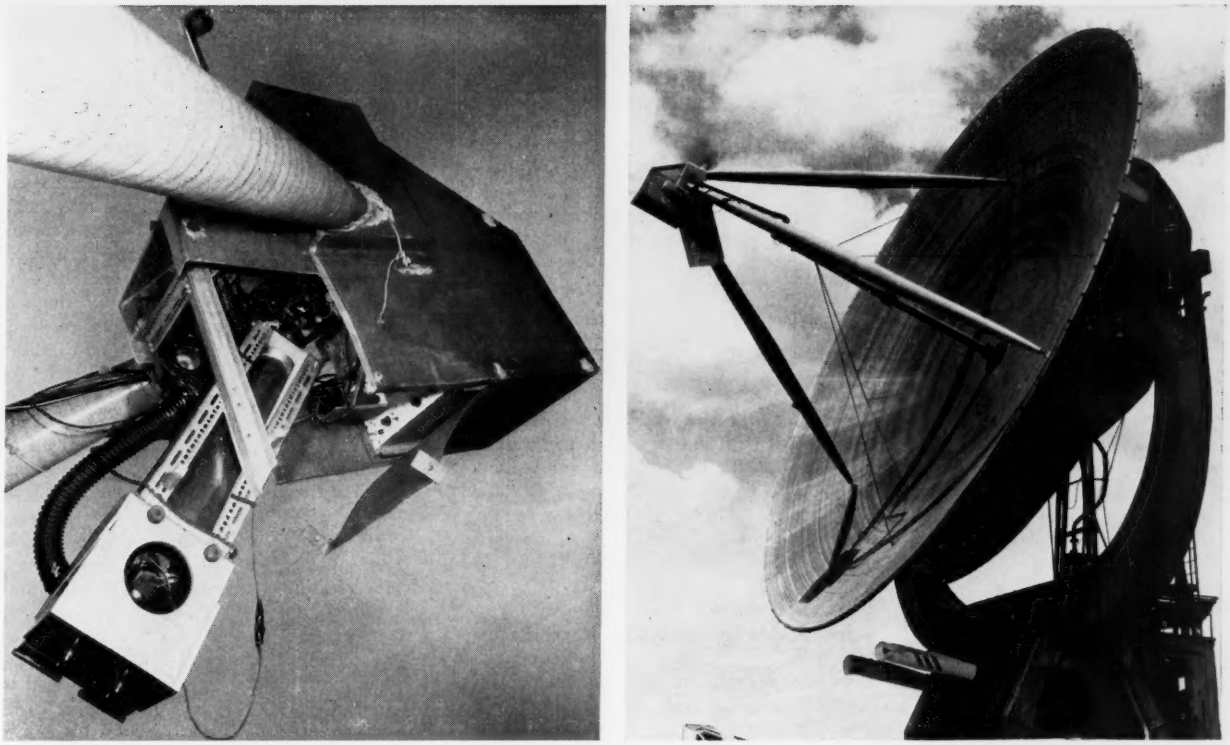


Fig. 5. At the right, the Columbia University maser is seen mounted on the Naval Research Laboratory's 50-foot radio telescope. In the close-up view at the left, the long cylinder extending downward contains the ruby maser itself, in a flask holding liquid helium. Naval Research Laboratory photographs.

Radio Astronomy Receivers—II

FRANK D. DRAKE, *National Radio Astronomy Observatory**

THE ULTIMATE LIMIT on radio telescope sensitivity is set by fluctuations in the radio noise generated by the receiver used. Last month we saw that the effect of these fluctuations could be greatly reduced by increasing receiver band-width and by observing for a long time. Nevertheless, the most effective way to improve sensitivity is to decrease the noise.

Until recent years, reductions in noise were obtained by improving the components of conventional radiometers. In particular, there has been a long succession of advances in the crystals used to beat, or heterodyne, the signals in a superheterodyne receiver. Ingenious circuits having low-noise properties have been invented and continuously improved. But this work using conventional electronics has fallen far short of producing a perfect receiver.

Radio astronomers usually describe noise in terms of the *excess receiver noise temperature*. This is a concept based on the fact that all hot bodies emit radio radiation. We can imagine any real receiver to be a fictitious ideal one, generating no noise within itself, with a hot resistor at its input. The gain and bandwidth will be the same as those of the real receiver in question. The hot resistor radiates noise power, which is amplified in the ideal unit and appears in the output like receiver noise. Evidently the excess receiver noise temperature is the temperature to which the hot resistor would have to be raised to give as much noise power out of the fictitious unit as is observed in the real one. This temperature is a direct measure of the noisiness of a receiver.

At the higher frequencies used in radio astronomy, say in the range 1,000 to 10,000 megacycles, the past 10 years or so have seen excess receiver noise temperatures drop from about 10,000° to about 1,000° absolute. The sensitivities have improved by a factor of 10, which is indeed a big step. But there is no physical reason preventing receivers from having nearly 0° noise temperatures — an additional improvement by a factor of 1,000 is available, if only technological problems can be solved. This would mean we could detect signals 1,000 times fainter than those we observe now, or see objects now barely visible even if they were 30 times farther away.

In the last few years, solid-state physics has given us two new extremely promising devices that can be used to build low-noise receivers. Both devices are amplifiers in which very little noise is generated. Before it enters a conventional receiver, the signal can be boosted to such a great strength that the receiver's noise no longer matters. The noise temperature of the system is then just the low noise temperature of the special amplifier.

The first of these special amplifiers is called a *maser,* a word made up from the first letters of the phrase "microwave amplification (by) stimulated emission (of) radiation," which describes very briefly the operating principle of the device. The maser makes use of the paramagnetic properties of certain crystals. This means that such crystals, when placed in a magnetic field, develop a system of unique energy levels in which some of the electrons of the substance must lie.

Electrons may go from one energy level to another by losing or gaining quanta of energy having a frequency given by the

*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.

same physical laws that govern atomic spectra. The situation is very similar to that in an atom, and the same effect results — the substance has a spectrum of line radiations associated with it. In many paramagnetic substances, the line frequencies are at radio rather than at optical frequencies. As in optical spectra, these line radiations are emitted or absorbed, depending on the character of the radiation falling on the crystal and the distribution of the available electrons among the energy levels.

One of the important processes that can occur in such a case is stimulated emission. Normally, when a photon whose wave length is that of a spectral line of a substance impinges on the substance, we expect the photon either to be absorbed or to go on its way unchanged. However, the laws of quantum mechanics require the occasional emission of a second photon of the same wave length as the first. This is the process of stimulated emission, and we obtain two photons where there was only one before — an amplification has occurred.

But a maser is not created quite this easily. In all normal materials, absorption exceeds stimulated emission in a given spectral line. This is because the laws of thermodynamics specify that there be more electrons in the lower energy levels than in the higher ones. Since absorption transitions involve electrons in the lower level connected with a line, whereas stimulated emission must involve an electron in an upper level, there are always more electrons ready to absorb than to emit a line. The effect of the application of signal photons would then be a net absorption of energy, rather than amplification. Somehow, the electron population of the various energy levels must be juggled so that some high levels have more electrons than low ones.

A way of doing this with crystals was

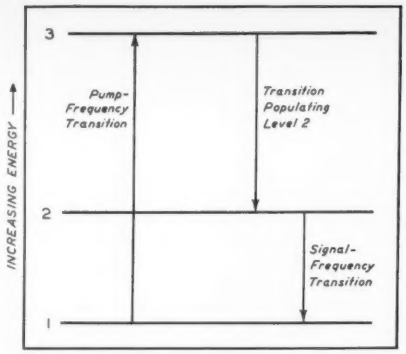


Fig. 6. Solid-state maser energy levels.

first proposed by N. Bloembergen at Harvard in 1956. In his scheme, three energy levels are used. Their values, and thus the frequency of the photons connecting them, can be changed by altering the strength or orientation of the magnetic field applied to the crystal. This makes it possible to "tune" the crystal to respond to a desired signal frequency.

Consider Fig. 6, a schematic diagram. Suppose we apply radio-frequency power to a crystal at the frequency corresponding to the transition from levels 1 to 3. This "pumps" many electrons into 3. Stimulated emission and ordinary spontaneous emission cause some of these to fall back to 1. As we strengthen the radio-frequency energy, usually called the *pump power,* a higher percentage of the electrons originally in 1 will be found in 3 at any given time. Finally, when the power is strong enough, the number of electrons in levels 1 and 3 will be equal. Any excess in 1 is immediately pumped to 3. Any excess in 3 immediately drops back to 1 due to stimulated emission.

Now what of level 2? Some of the electrons fall spontaneously from 3 to 2, keeping that level populated. But the population of 2 will not equal that of the other levels except by a rare coincidence. What Bloembergen noticed was this: If there are *fewer* electrons in level 2 than in 1 and 3, stimulated emission will dominate absorption when photons associated with the transition between levels 2 and 3 fall on the crystal. On the other hand, if there are *more* electrons in level 2 than in the others, stimulated emission will exceed absorption for photons associated with the jump between levels 1 and 2. This is the case depicted in the diagram. No matter what the population of level 2 is, one of the upper levels has more electrons than the level below it, and amplification of the appropriate frequency is assured.

Efficient and practical maser operation can only be obtained at temperatures near absolute zero, so the device usually is immersed in liquid helium at about 1° K. This becomes nearly the excess receiver noise temperature of the device, and a maser can be 1,000 times better for radio astronomy than a conventional receiver.

Nevertheless, there are a large number of problems connected with masers that have prevented their widespread use. One of the earliest was to obtain large, high-quality, paramagnetic crystals. It turns out that about the best substances for maser use are the well-known ruby and sapphire gems. Stones weighing hundreds of carats are required to make good masers! It is not surprising that this proved a stumbling block in the path of science. However, techniques for making such stones artificially are now in wide use. It is startling to enter some modern electronics laboratories and find rooms without a single voltmeter or soldering iron; where, instead, there are refrigerators and vats of chemicals with which people are merrily producing gigantic rubies and sapphires at a rate of one per hour or so.

Having to immerse the device in liquid helium also creates many difficulties. Liquid helium is not generally available, is expensive to purchase and troublesome to transport. The very low temperatures around the maser cause rapid formation of frost, which freezes and clogs the mechanism. Movement of the radio telescope as observations are made changes the position of the liquid helium in the device, affecting the cooling of various parts of the apparatus. And one must always beware lest helium be spilled out.

Much work is being done to eliminate these problems, too. Before long, there should be a completely closed liquid-helium refrigerator in which masers may be immersed. It will be immune to the problems mentioned, will provide low temperatures indefinitely, and require no more attention from the astronomer than an occasional check to see that it is still plugged in.

In one of radio astronomy's most exciting pioneering efforts, scientists at the Naval Research Laboratory and Columbia

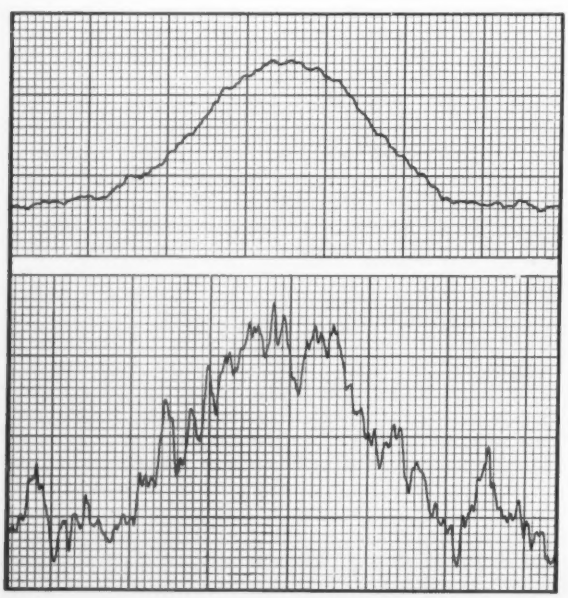


Fig. 7. Drift scans of the strong Cygnus A radio source at a wave length of about three centimeters, made with a conventional superheterodyne receiver circuit and the equipment illustrated in Fig. 5. The lower tracing was made without the maser, at 9530 megacycles per second with a band-width of 11 megacycles; the upper with the maser at 9390 megacycles and five-megacycle band-width. The integrating time in each case was five seconds. The fluctuations are due to receiver noise, which is reduced to one-tenth of its value when the maser is used. Naval Research Laboratory chart.

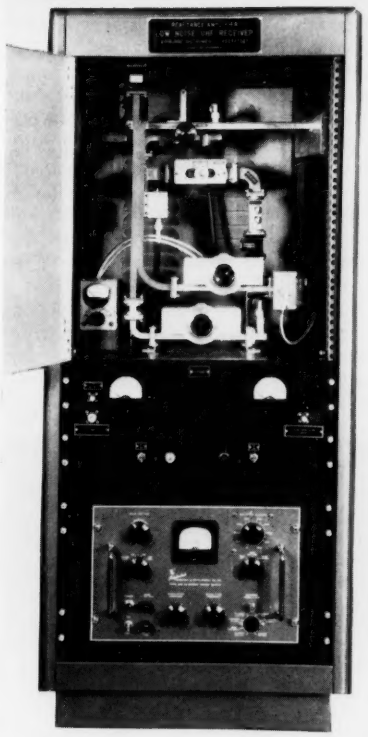


Fig. 8. A reactance amplifier for a frequency of 440 megacycles, built by Airborne Instruments Laboratory. The excess receiver noise temperature of this system is about 100° Kelvin.

University built a special maser and used it on the NRL 50-foot radio telescope. Through actual observations of celestial radio sources, this experiment showed that the maser gives in practice every bit of the improvement predicted theoretically. Fig. 7 illustrates observations of the Cygnus A radio source made with a conventional receiver and the 50-foot antenna, and then with the same setup and a maser. Fluctuations in the tracings, which are entirely due to radiometer noise, are reduced by a factor of at least 10. At the time of this experiment, certain important components were still not available, with the result that the over-all radiometer noise temperature was about 85° K. It should now be possible to improve the system by another factor of 10.

The second device giving low noise amplification is the *reactance* or *parametric* amplifier. The action of this amplifier can be described as being similar to that of a child on a swing. If he exerts force on the swing repeatedly, at the frequency at which it naturally moves, and during the proper portion of the to-and-fro movement, he can make the swing go higher. In the reactance amplifier, the swing is replaced by a special crystal that acts electrically like a capacitor. Its capacitance is variable, and dependent on the voltage applied to it. The child is represented by a strong source of radio-frequency power, again called the pump. When an alternating signal voltage of the right frequency enters the system, the pump power, acting through the special crystal, causes the strength of the signal alternations to increase, and again there is amplification.

Many sophisticated reactance amplifier designs have been developed, and today there is a profusion of different forms of this device. Some give more gain, or more gain stability, or require less pump power, or have different relationships between pump and signal frequencies. But all use virtually the same crystal and nearly the same principle of operation.

In theory, these amplifiers could be noiseless if the crystals were perfect and acted as pure capacitances. This is true even though the temperature of the entire device may be near room temperature, 290° K. However, existing crystals have a little resistor action as well as capacitor action, and unless the crystal is operated near absolute zero, this small "resistor" radiates a little noise into the system. In practice, typical excess noise temperatures measured in the best of these devices have been in the range 50° to 150° K. Thus, they are not nearly as good as masers, especially at high frequencies. But, since the over-all noise in a maser system may be as much as 85° K, radiometers using present reactance amplifiers can nearly compete with masers. Further improvements in crystals may give nearly perfect performance.

The reactance amplifier has great appeal to radio astronomers. It is but little different electronically from ordinary amplifiers, and is inexpensive. Liquid helium is not necessary, so most of the large operating expenses and serious problems of masers do not occur. A reactance amplifier can be moved readily into any orientation without loss of performance.

These devices would have seen extensive use already, but early models were plagued by a serious lack of gain stability. As mentioned last month, this can be as harmful as noise in radio astronomy observations, and the early reactance amplifiers only served to prove the point. However, this problem is solved now, and several refined models are commercially available (Figs. 8 and 9).

What will it mean to scientists to have receiver noise temperatures of only about 10° K? Of course, we shall be able to study in greater detail the objects already within reach of our radio telescopes, and to observe many more of them. With very large antennas, such as the 600-foot and 140-foot dishes now under construction, it will probably be possible to detect the radio radiation from some of the nearby stars, and almost certainly from flare stars. Thus we may study flares and sunspot-like phenomena on stars other than the sun.

By radar techniques, we could analyze the surface structures of all the planets except Neptune and Pluto. We will be able to map in detail the distribution of neutral hydrogen and of ionized hydrogen regions in the Andromeda nebula and other nearby galaxies. It should be feasible to observe radio sources at the "edge" of the universe, and possibly to find thereby which theory of the evolution of the universe is most plausible.

One of the most exciting possibilities will come from our ability to detect radio signals from beings on other planets over interstellar distances. Some of the radar transmitters now in use on earth could be placed almost 100 light-years away in space and still be detected by a 600-foot antenna and one of the new low-noise amplifiers! And we must remember that even these radars represent only a few years of development — much more powerful ones can obviously be built here and perhaps elsewhere. There are over 10,000 stars within 100 light-years of the earth, and many are nearly identical to the sun. If on planets near any of those stars there are beings as advanced as we, it might be possible to identify the output of their radio equipment. Can we thus study, in our own lifetimes, intelligent life on other planets? This would be a feat unattainable by any other means.

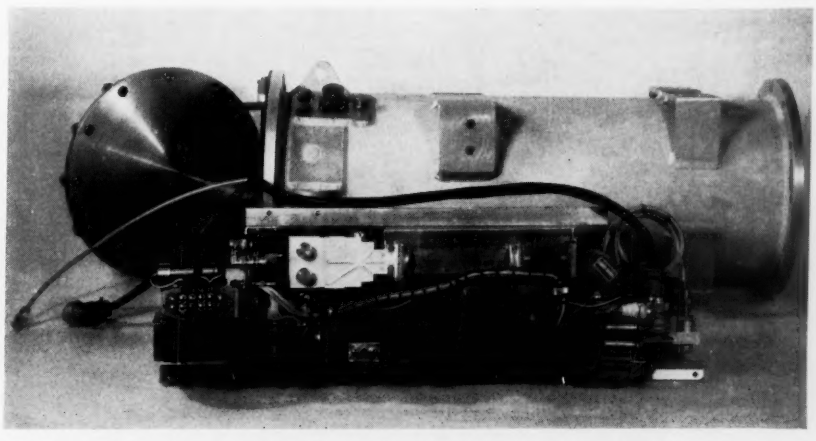


Fig. 9. A reactance amplifier for 960 megacycles, the telemetry frequency for many American space probes. The amplifier is in the foreground, and the cylinder is its airtight case. This unit's excess noise level is 150° Kelvin. Photographs on this page are courtesy Airborne Instruments Laboratory.

OBSERVING THE SATELLITES

Explorer VII

LAST in the American series of artificial satellites for the International Geophysical Year, Explorer VII was launched from Cape Canaveral on October 13th at 15:30:05 Universal time. Shaped like a stubby cylinder capped by two cones, this "IGY heavy" satellite is 20 inches in diameter and 20 inches high, weighing 91.5 pounds.

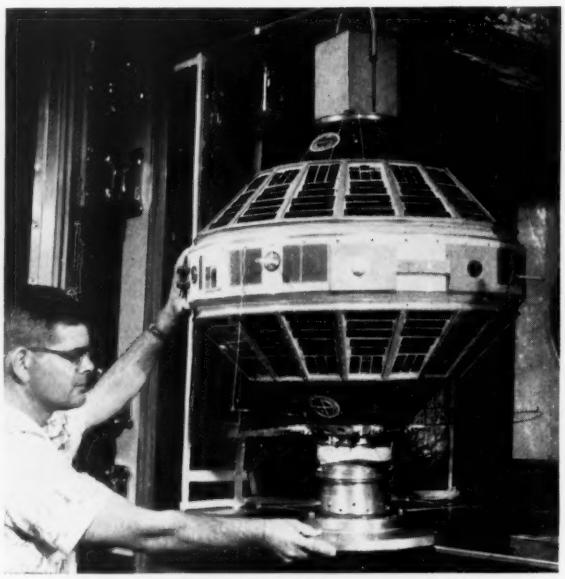
An earlier attempt to place the same kind of IGY package in orbit failed on July 16, 1959, when the launching rocket veered off course and was blown up by the range safety officer. (The trouble had been a short circuit in the guidance system's power supply.)

For the successful October operation, the launching vehicle was a Juno II, much like the one that put Pioneer IV into an orbit around the sun on March 3rd. The guidance system for the first-stage Jupiter, carried inside the vehicle, consisted of a computer that compared a tape-recorded flight program with performance data supplied by a gyro-stabilized inertial platform. Both the second and third stages were powered by rapidly spinning clusters of solid-fuel Sergeant rockets, each six inches in diameter and scaled down to 42.5 inches long, firing in sequence. The final-stage rocket was a similar Sergeant, which brought the payload into orbit about 10 minutes and 54 seconds after lift-off.

Of the seven programs of measurements being made by Explorer VII's instruments, perhaps the most important concerns the radiation balance of the earth. As averaged over a few years, the energy which the earth and its atmosphere receive from the sun nearly equals that sent back into space. Part of the solar energy is reflected, the rest absorbed and radiated again at longer wave lengths. The earth's weather is profoundly affected by the facts that energy intake is relatively greater near the equator, and that radiation outflow predominates from the polar regions.

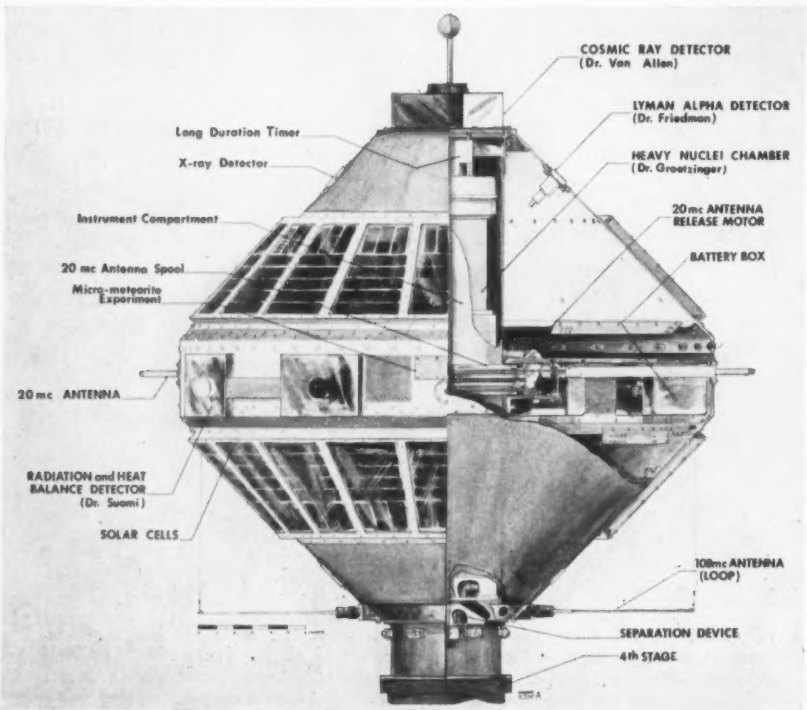
To ascertain the budget of incoming and emitted radiation, the satellite carries three pairs of sensors. Black-painted $1\frac{1}{4}$-inch hemispheres measure the total energy at all wave lengths, while white ones of the same size respond chiefly to longer-wave-length heat radiation. Two specially coated one-inch Tabor sensors determine short-wave radiation. The interpretation of these measurements requires information concerning the satellite's geographical latitude and the direction to the sun from moment to moment.

The effects of solar flares upon the sun's radiation are being studied by Explorer VII in Lyman-alpha light of hydrogen at 1216 angstroms, and in X-rays of three to 15 angstroms. Each spectral region is recorded by an ion chamber about $\frac{3}{4}$ inch in diameter and $1\frac{1}{4}$ inches long. The Lyman-alpha counter is covered by a lithium-fluoride window, the X-ray counter by one of beryllium. The equipment for this study includes a photocell to determine the orientation of these ion chambers relative to the sun.



Right: A technician in the guidance and control laboratory at the Army Ballistic Missile Agency, Huntsville, Alabama, puts Explorer VII's equipment for measuring composite radiation into a vacuum chamber to test its performance. Official U. S. Army photograph.

Below: An artist's drawing of the Explorer VII package, which is now conducting seven different types of measurements, including the radiation and heat balance of the earth. Illustrations from the National Aeronautics and Space Administration.



Two experiments are devoted to cosmic rays. Counts of total cosmic ray intensity are being made with two small Geiger tubes, one shielded by a millimeter of lead. A special ion chamber analyzes fast-moving heavy primary cosmic rays. This device counts the numbers of incoming particles in three classes: those with atomic numbers equal to or greater than 3 (lithium), 6 (carbon), and 9 (fluorine), respectively. The design of this apparatus is based on the assumption that all of the particles encountered will be traveling at least 0.9 as fast as light.

Much of the satellite's shell is covered with a total of 2,886 silicon solar-energy converters that recharge nickel-cadmium batteries. Weighing 22.5 pounds, the power-supply system provides about 2.6 watts continuously for the experiments and the telemetry transmitters. While the silicon cells are protected by fused-silica glass, one uncovered cell is included to test the damaging effects of the space environment on its rated performance.

Explorer VII is telemetering its experimental data at a fundamental frequency of 19.9904 megacycles, with amplitude modulation, together with second and third harmonics at greatly reduced power. These three frequencies are readily received by usual amateur radio equipment. Another transmitter operating at 108.0003 megacycles furnishes signals used by Minitrack stations for following the orbital motion of Explorer VII. This transmission is phase-modulated by the satellite's equipment for detecting micrometeorites. Particles of 10 microns or more in diameter are recorded by a photoconductor cell covered with an opaque film that is punctured by impact.

In accordance with a recent international agreement, the satellite carries a clock that will automatically shut off its transmitters after one year in orbit. This is a precaution to prevent cluttering of the radio spectrum for the indefinite future.

The Explorer VII satellite has received the designation 1959ι1. Initially, it was circling the earth every 101.3 minutes, in an orbit inclined 50.3 degrees to the equator. At its apogee, the satellite reaches a height of about 675 miles, and at perigee descends to about 342 miles. Probably the final-stage rocket, 1959ι2, travels in a closely similar orbit, with a period only about 1.2 seconds shorter than that of the instrument package.

Lunik III

LAUNCHED on October 4th, the Soviet space probe Lunik III continues in its immense orbit around the earth, after accomplishing the spectacular mission of photographing the moon's far side. The first picture released is described on page 72; the present discussion of the vehicle and its motion extends the account on page 13 of last month's issue.

The rapid rotation of the probe was halted by jets of gas at about 3:30 UT on October 7th. During the next 40 minutes, the stabilized satellite took photographs of the lunar surface from 37,300 to 43,500 miles above it. Two camera lenses, of 200 and of 500 millimeters focal length, were used. Then the 35-mm. film was developed and fixed at a temperature of 25° centigrade, maintained inside the satellite by radiation shutters.

Later the films were televised over the same frequency channel used for tracking the satellite and telemetering its experiments. When the transmissions began, at 274,000 miles from Earth, they were relatively slow, but became more rapid as the distance lessened — an arrangement to maintain a satisfactory signal-to-noise ratio.

All of the film was exposed on October 7th, because Lunik III then passed closer to the moon than on its next few revolutions, as shown by the diagram at the lower right.

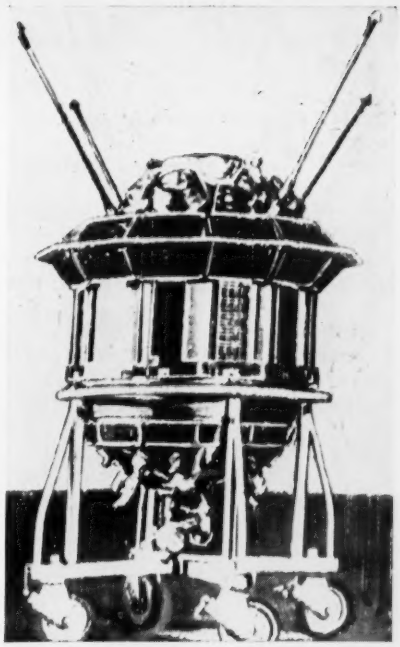
The path of the Soviet probe on its approach to the moon is represented on the other chart, prepared by the Smithsonian Astrophysical Observatory. On October 6th, Lunik III passed less than 5,000 miles from the moon's south pole. This close approach resulted in a radical modification of the object's orbit. After the satellite had receded far enough from the moon for the earth's attraction to dominate once more, it was moving in a highly elongated ellipse that lay in a plane inclined about 86 degrees to the moon's orbital plane.

According to Smithsonian calculations based upon Soviet news releases, the eccentricity of this orbit is 0.824, greater than that for any other satellite known, natural or artificial. (Neptune's second moon, Nereid, is runner-up with 0.749.) The distance of Lunik III in its present orbit varies between 29,000 miles from the center of the earth, at perigee, and about 300,000 miles at apogee. The period is now about 15.76 days, perigee having been passed on October 18th at 16:49 UT.

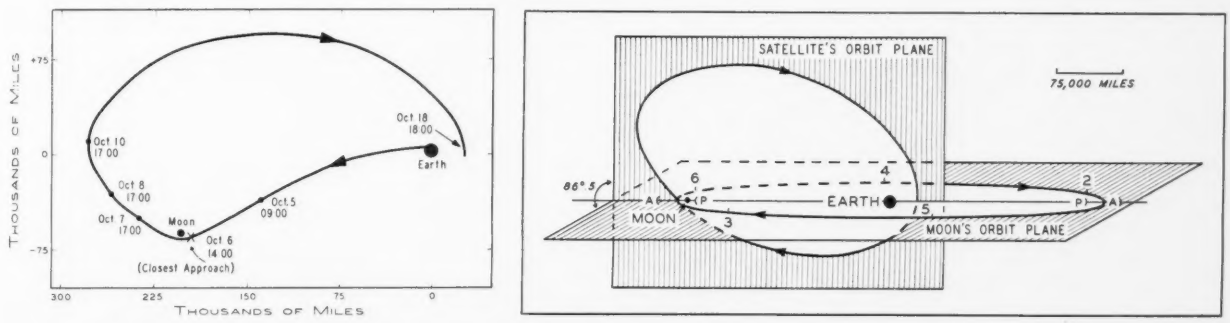
According to the Soviet press, the lifetime of Lunik III may be as short as six months. The orbital problem is, however, very difficult, and any forecast of the motion more than a revolution or two in advance requires step-by-step computation of the gravitational perturbations by the moon and the sun.

The designation 1959ϑ1 has been used by Space Track for Lunik III. Presumably the accompanying rocket should be called 1959ϑ2, but nothing has been reported about it recently.

MARSHALL MELIN
Research Station for Satellite Observation
P. O. Box 4, Cambridge 38, Mass.



Lunik III carries four radio antennas on its nose section, which contains the two cameras that photographed the moon's other side. This instrument package weighs 614 pounds, is 87 inches long and 47 inches in diameter. Wide World photograph.



The orbit of Lunik III, showing at the left its initial approach to the moon, as deduced by C. A. Whitney, Smithsonian Astrophysical Observatory. The moon's attraction changed the path to a plane nearly perpendicular to the lunar orbit, as shown at the right. The moon's path is drawn for its mean distance from the earth, with the letters A and P marking the maximum and minimum possible distances. The moon's position is shown as a dot for the October 6th encounter. When Lunik III had swung around the earth and was near that place again, however, the moon was at position 2; on the next return of Lunik III the lunar location was 3, and so on. Thus, another close encounter would not occur for many revolutions of the artificial satellite. The author's chart is based on orbital elements released by the Smithsonian Astrophysical Observatory.

ASTRONOMICAL SCRAPBOOK

A Plato Illusion

SOME important consequences can be traced from a simple fact about the moon, obvious to even casual naked-eye viewing. At full phase our satellite gives far more light than at its quarters, 11 times as much according to measurements. But since the illuminated area has only doubled, evidently the brightness per unit area increases toward full moon.

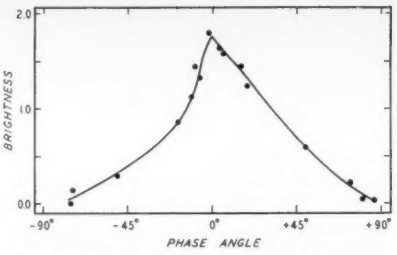
During the past 60 years, many astronomers have devoted much labor to photometric measurements of limited areas on the lunar disk, to trace how their brightnesses change with phase. Some of this work was done in Germany and the United States, but mainly in the Soviet Union, and therefore has been relatively inaccessible to American amateurs.

Perhaps the most extensive of these investigations was the one published in 1952 by V. A. Fedorev in the *Annals* of Kharkov Observatory. During 1948-49, 40 photographs of the moon were taken with a 6-inch refractor, and on these the brightnesses of 170 small areas were measured. Since all the photographs carried calibration marks, the observations on different plates could be expressed on the same scale. In all, about 50,000 microphotometer settings were made.

In this way, light curves were obtained for 170 lunar regions. In every case, the curve rose to a peak at full moon (strictly speaking, at phase angle 0°). That is, all the areas, irrespective of their position on the moon, brightened and faded together during the lunar month. The places near the eastern edge of the disk, where sunrise occurs shortly before full, brightened much more rapidly than did areas near the western edge, where the sun had risen nearly two weeks before. This fact deserves emphasis, for there is a widespread misconception among amateur lunar observers that any particular point on the moon should appear brightest when the sun's angle of elevation is greatest there.

Darker parts of the moon, such as the maria, produced light curves with lower peaks than those for bright plains and mountainous regions. Similar in this respect to the seas is Fedorev's area 56, which is the floor of the crater Plato. Its light curve, shown here, is of particular interest in refuting a century-old myth.

Even in very small telescopes, the broad, level floor of Plato attracts the eye as a steel gray oval surrounded by bright highlands. It is conspicuous even on the full moon, when neighboring formations are shrouded in glare. Nearly a hundred years ago, this suggested to the British amateur W. R. Birt that the interior of Plato was actually darker when illuminated by a high sun — becoming grayer as the sun rose in its sky and brightening again as the sun descended.



The changes in the brightness of the crater Plato with lunar phase are shown by V. A. Fedorev's measurements. Contrary to an old belief, Plato is brightest at full moon (phase angle 0°), like all other level lunar areas observed photometrically.

This phenomenon was eagerly accepted by Birt and his fellow observers as an indication of some physical change occurring on the moon each month. In 1871 he published a detailed discussion of 133 descriptions of Plato, seemingly a complete confirmation of its anomalous behavior. It must be remembered that then no surface photometry of the moon had ever been tried, and that Birt's observational material consisted only of visual impressions.

In this way there came into English-language lunar literature the statement that Plato's floor darkens under a high sun, a story copied with various embellishments in the books of E. Neison (1876), T. G. Elger (1895), and W. Goodacre (1931). Only quite recently have amateur lunar specialists begun to express disbelief, for example W. H. Haas in 1942 and H. P. Wilkins in 1950.

The explanation of this long-continued misunderstanding is evident when Fedorev's data are considered. The visual observer who has no photometric standard can only compare Plato with its surroundings. Because these brighten more toward full than does the crater floor, the latter seems to darken.

The demonstration of Birt's mistake does not depend on the Fedorev observations alone. Other series, such as the visual photometry of V. Scharonov and N. N. Sytinskaya, and the photoelectric measurements by A. V. Markov, all show the enhanced luster of Plato at full moon.

The Plato illusion is not an isolated case. In the years just before 1900, W. H. Pickering called attention to many smaller dusky lunar markings, which he believed to show the same darkening as Plato. These features included the dark spots in Alphonsus, Riccioli, and Atlas. Pickering, largely on the strength of this, became a firm believer in the existence of periodic changes on the moon, even going so far as to suggest lunar vegetation as a cause! More probably, since he made no photometric observations of these spots, they misled him in the same way that Plato had misled Birt.

JOSEPH ASHBROOK

The darkness of Plato's floor, compared with its surroundings, is easily seen in this enlargement from a photograph taken with the 100-inch Mount Wilson reflector. At the top (south) in Mare Imbrium is the mountain Pico, which with other hills and ridges marks the sketchy outline of the large oval sometimes called "ancient Newton." Note the interior craterlets in Plato.

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 103rd meeting of the American Astronomical Society at Toronto, Canada, Aug. 30-Sept. 2, 1959. Complete abstracts will appear in the Astronomical Journal.

Unusual Star Cluster Messier 71

Located in Sagitta in a rich Milky Way field, Messier 71 (NGC 6838) is a conspicuous, highly concentrated cluster of faint stars. Astronomers have long debated whether this grouping is an especially compact open cluster, or a relatively poor globular one. The former classification was suggested by M71's location in the Milky Way, and by the lack of cluster-type variables among its members. In favor of assignment to the globular class were two observational facts: the redness of the brightest stars in the system, and the large velocity of approach, 80 kilometers per second.

The characteristics of M71 have now been studied by James Cuffey, Indiana University. He measured the colors and magnitudes of a large number of stars belonging to it, photoelectrically with the 82-inch reflector of McDonald Observatory, and on photographs taken with the 100-inch Mount Wilson telescope. These observations give a color-magnitude diagram, each plotted point representing a star in the central part of the cluster.

The diagram shows at once that M71 is not a typical open cluster, as there is no main sequence extending from upper left to lower right. However, Dr. Cuffey notes three features of the chart that demonstrate differences from ordinary globulars. The red-giant sequence (upper right) has a large scatter, which cannot be due to observational errors. The same branch near magnitude 14 shows an abnormal slope, not known for any globular cluster. There is no horizontal branch of white stars, such as would be expected at the left side of the diagram.

For these reasons, the Indiana astronomer believes that M71 must be regarded as an unusual cluster, and not as a globular. This conclusion means that previous distance estimates of the system are in error, having been based on wrong premises. Also, future calculations of the rotation of the galaxy, based on the measured radial velocities of globular clusters, should exclude M71.

Dr. Cuffey is continuing his photoelectric observations, especially of the faintest stars in the cluster.

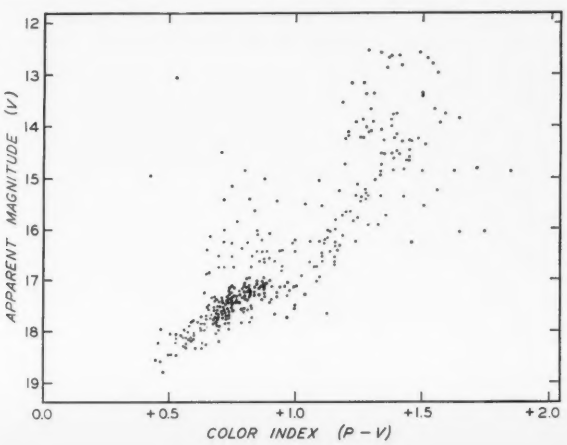
The star cluster Messier 71, shown in a 1.8-times enlargement from a photograph taken in blue light by the Palomar Observatory 48-inch Schmidt telescope. The classification of this stellar system has been debated among astronomers for years. North is above.

Microwave Study of the Moon

At the U. S. Naval Research Laboratory, Robert J. Coates has been measuring lunar radiation of 4.3-millimeter wave length, with the aid of an equatorially mounted paraboloidal antenna 10 feet in diameter. By making repeated television-type scans across the moon's disk, it was possible to construct crude lunar maps for different phases. Because the angular resolution was 6.7 minutes of arc, compared with the moon's 31-minute average diameter, the larger surface features are recognizable.

Such charts show primarily the distribution of temperature over the lunar disk. In particular, Dr. Coates found that the large, dark, level areas (maria) warm up more rapidly toward full moon and afterward cool more rapidly than do the "continental" parts of the moon. However, Mare Imbrium is an exception to this general rule.

The project was a continuation of previous NRL observations made at a wave length of about eight millimeters. Dr. Coates pointed out that establishment of the manner in which lunar microwave radiation changes with wave length will make it possible to compute important physical characteristics of the moon's surface.



James Cuffey has here plotted his measurements of brightnesses and colors of stars in the central part of the cluster M71. As explained in the text, abnormal features of the diagram place the cluster in a class by itself. Indiana University chart.

Variable Stars in the Scutum Cloud

A conspicuous bright patch of Milky Way between Aquila and Sagittarius forms the Scutum starcloud, which long-exposure photographs show to be an exceedingly rich field of faint stars. Since the early 1920's, many variables in the Scutum region have been discovered and studied by Margaret Harwood and her associates at Maria Mitchell Observatory, Nantucket, Massachusetts. The work has mainly used photographs taken with its 7½-inch refractor, and plates loaned by Harvard Observatory.

This major variable star survey has now been completed, and the new results are ready for publication. Of 528 variables within the cloud, 338 are previously uncatalogued objects discovered at Nantucket. Most are rather faint stars, of magnitude 14, 15, or 16 at maximum light; and minima down to 18.4 have been observed.

According to Dr. Harwood, 27 per cent of the variables now known in the Scutum cloud are of the long-period type;

21 per cent are eclipsing systems; 19 per cent are irregular; and 16 per cent are of the RR Lyrae type.

Victor Blanco, of Warner and Swasey Observatory, furnished Miss Harwood with spectral classifications for 183 of the long-period and irregular variables. In a like example of collaboration, Lick Observatory astronomer Gerald Kron provided photoelectric measurements, with the 36-inch reflector, of the brightnesses of stars in Scutum, for magnitude calibration of the Nantucket sequences of comparison stars.

Absolute Magnitude of X Monocerotis

In the 1958 edition of the Moscow *General Catalogue of Variable Stars,* X Monocerotis is listed as a semiregular star, varying between magnitudes 6.9 and 10.0 in a period of 156 days. On the basis of its spectral characteristics, however, Philip C. Keenan, Perkins Observatory, regards it as probably a Mira-type star. He calls attention to it as one of the few such objects for which a reliable individual distance can be measured. Except perhaps for Omicron Ceti itself, all Mira stars are too remote for good trigonometric parallax determinations.

Because X Monocerotis is moving toward us at a rate of 142 kilometers per second, spectral lines originating in the star's atmosphere are shifted considerably toward shorter wave lengths. Consequently, the sharp and relatively undisplaced lines produced by interstellar gas can be observed without masking by the corresponding stellar lines, which are much stronger.

In principle, if one star very close to another in the sky were to have interstellar lines of the same intensity, the two stars should be at the same distance from us. Dr. Keenan applied this method to X Monocerotis, observing with the coude spectrograph of the 100-inch Mount Wilson telescope. Four stars of spectral type *A* or *B,* located within a degree of the variable, all showed slightly stronger interstellar lines than it does. From this he concluded that X Monocerotis is about 350 parsecs (1,150 light-years) away, and that at maximum light it has a visual absolute magnitude of −0.7. This is somewhat less luminous than the average for Mira stars of similar period, using distances deduced from their motions.

Shattered Rocks Beneath Meteorite Craters Compared

Further evidence has been obtained that the same mechanical processes shattered the rock under the floors of the Barringer meteorite crater in Arizona and the Holleford crater in Ontario. The similarity of these scars on the earth's surface had already been established by their depths, diameters, and profiles.

This current work was reported by C. S. Beals, Dominion Observatory, and P. M. Millman, National Research Council of Canada, who carefully compared the nonmeteoritic subsurface materials of the two craters. The Barringer crater samples came from various levels in a shaft 50 feet deep, located 500 feet from the crater's center, as well as out of a 350-foot horizontal tunnel dug into the inner crater wall 350 feet vertically below the rim. The specimens ranged in size from irregular pieces several inches across down to microscopic grains of dust.

Drill cores were obtained from the Holleford crater at distances of 1,400 feet, 2,500 feet, and 3,750 feet from the center, and at depths between 65 and 1,128 feet. Some of these cores are illustrated in Dr. Beals' article in the September, 1957, issue of SKY AND TELESCOPE (page 526). They contained fragments with sizes from gross rocks to microscopic particles.

A mixture of the Barringer crater materials was set in cement and drilled. The resulting artificial cores showed a remarkable similarity to the drill cores from Holleford, though the latter were mostly of a darker color. The Canadian scientists concluded that the material of both craters seems to have been produced *in situ,* with a minimum of subsequent transportation by wind and water.

Polarization of Light of Moon and Planets

A paper by Indiana University astronomer Thomas Gehrels was reported under this heading on pages 17 and 18 in the November issue. He now makes the following changes: On page 18, 17th line in first column, substitute 9900 for 10,330 angstroms. In the second column, make the third line read in part, "of 3500, 5500, and 8300 angstroms," and delete the sentence, "These indicate interstellar particle sizes of a few microns."

LETTERS

Sir:

Several points in Otto Struve's article on the age of the earth (June, 1959, issue of SKY AND TELESCOPE, page 433) deserve some comment and criticism.

First, on page 434 in the middle column, the author assumes that the crust of the earth would float on molten magma beneath the crust. Solid silicates do not float on their liquids. In fact, water is the only common substance whose solid phase floats on its liquid. Though it is not important to Struve's argument, so far as I can see this error is a common one made by astronomers and has appeared in the literature repeatedly in the last decade. The correct solidification of silicates was recognized by Lord Kelvin in 1862, when he discussed a molten earth and concluded that it would solidify from the core outward.

In telling of the consequences F. G. Houtermans drew from the differing lead-isotope ratios in iron meteorites, the article does not mention the scientists responsible for this work. Claire Patterson, Harrison Brown, Mark Inghram, and George Tilton measured the relative abundances of the isotopes of lead in two iron meteorites. (Only two have been investigated, not many, as the article states.) They reported their work at a conference held at Williams Bay, Wisconsin, in September, 1953, and at that time concluded that the age indicated by the methods discussed by Struve was 4.5 billion years. They also presented their results to the Geological Society in November of that year.

Dr. Struve's interpretation of the significance of the age is, I think, incorrect. The age so found is only the interval since the iron meteorites became separated from lead and thorium. Only by inference does it fix anything about the age of the earth or any other body, nor does it tell us whether the earth was molten at the time of its formation. Other methods of dating meteorites (potassium-argon and rubidium-strontium measurements) give very similar ages, and hence it appears that a very complicated set of chemical reactions took place about 4.5 billion years ago. It is reasonable to associate this set of reactions with the processes that led to formation of the solar system generally.

HAROLD C. UREY
University of California
La Jolla, California

QUESTIONS... FROM THE S+T MAILBAG

Q. When was the first successful photograph of the moon taken?

A. The first was probably the daguerreotype made in 1840 by the American amateur astronomer J. W. Draper.

Q. How many professional astronomers are there in the United States?

A. Approximately 500, according to J. A. Hynek, secretary of the American Astronomical Society.

Q. When will Halley's comet next return to perihelion?

A. About 1986. An accurate prediction will require lengthy calculations of how the comet's motion is disturbed by planetary attractions. The Argentine astronomer Jorge Bobone was working on this problem when he died last year.

Q. Which are the seven largest refracting telescopes in the United States?

A. The 40-inch at Yerkes Observatory; 36-inch at Lick; 30-inch at Allegheny; 26-inch instruments at the McCormick and U. S. Naval observatories; and 24-inch ones at Lowell and Sproul.

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OBSERVER'S PAGE

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AMATEUR OBSERVATIONS OF OCTOBER'S ECLIPSE

BECAUSE cloudy skies covered the path of totality in New England, successful observations of the corona during October 2nd's total eclipse of the sun were possible there only from aircraft. One airborne group, headed by Stanley W. Brower of Plainfield, New Jersey, flew from Newark to arrive over the Massachusetts coast in time to photograph totality. Their pictures, taken at 8,200 feet, showed the upper part of the solar corona, but the lower part of the sun's disk was behind a cloud layer.

A Worcester amateur, T. L. Agos, photographed the total phase of the event from 15,000 feet over Boston in an Air Force C-119 flying boxcar. Another photographic party was Caroline Evans and Dr. R. C. Gunter, of Clark University, who flew 10,000 feet over eastern Massachusetts to secure pictures of the sun just after third contact.

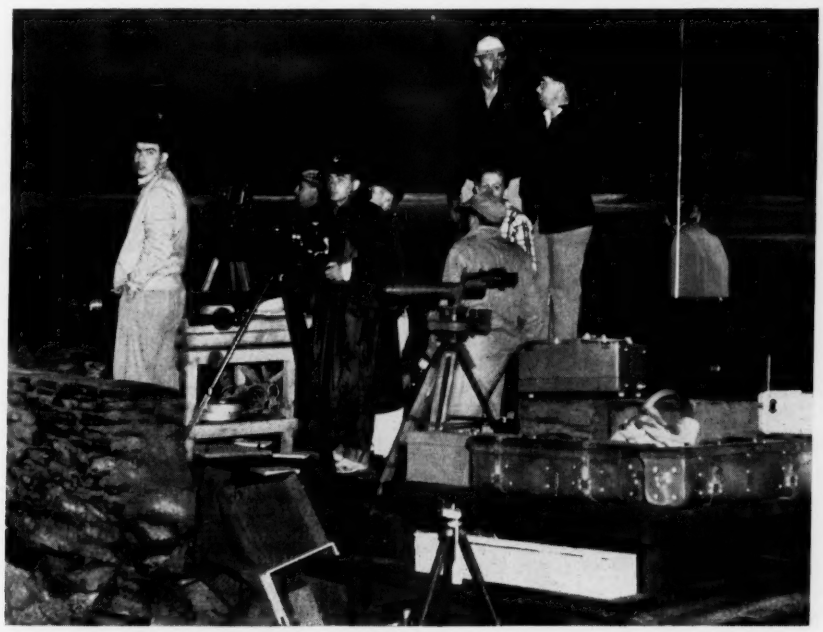
But in other parts of the northeastern United States and in Canada, many amateur astronomers were able to view and film the partial phases of the eclipse. Accounts of such observations have been received from Montreal to Maryland. The Montreal Centre of the Royal Astronomical Society of Canada reported in its October newsletter, *Skyward,* that many members gathered on Westmount Mountain, but clouds hid the sun until the eclipse was nearly over.

However, F. J. DeKinder, who stayed at his home in Montreal North, saw the sun still 50-per-cent covered by the moon at 6:15 a.m. Eastern standard time. High in the eastern sky, Venus was visible to add to the spectacle. Mrs. W. M. Wilson, at Lake Macdonald in the Laurentians, enjoyed perfect weather and watched the partially eclipsed sun rise.

In Connecticut, E. H. Thielens, observing about 14 miles north of Stamford, secured pictures of the sun during the final stages. J. E. Bortle, at Mt. Vernon, New York, took six photographs of the eclipse, one of which is on the next page. He also saw the moon's shadow in the atmosphere, despite interference by clouds. Two other accounts from the New York City area describe photographic work by M. Hurwitz, of Brooklyn, and a successful watch by six members of the Grumman Astronomical Society at Bethpage, who saw the sun 65-per-cent covered.

A series of 10 sketches of the eclipse as viewed through a 6-inch reflector was made by A. Burstiner, Etters, Pennsylvania, where the sun emerged from clouds at 6:15 a.m. EST. The most southerly report of successful observations came from Mr. and Mrs. W. M. McKeeman, Annapolis, Maryland, who also sketched the event. The half-hidden sun became visible for them at 6:06 a.m. EST.

Many amateurs made unsuccessful attempts to observe the eclipse. They included D. R. Miller, Blakeslee, Pennsylvania, who watched at Marblehead, Massachusetts; Barbara Federer, at Ithaca,



Members of a joint expedition of the Worcester Museum of Natural History and the Aldrich Astronomical Society stand by their equipment, to be used in elaborate studies of the eclipse, as they peer into the murky skies over Mt. Wachusett, Massachusetts. The same groups sponsored two successful airplane missions. Photograph by Elman B. Myers.

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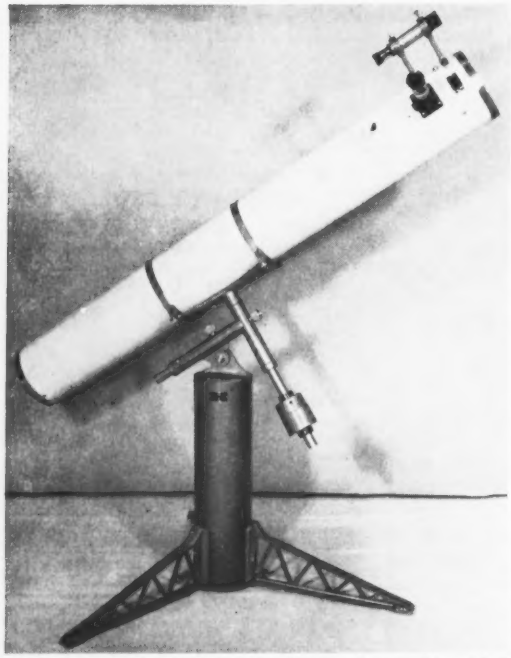

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Just as the sun was rising above a cloud bank at Mt. Vernon, New York, John E. Bortle photographed the partial phase at 6:20 a.m. Eastern standard time. He used an f/15 2.4-inch refractor and Unitron astro-camera with Super Pancro Press film.

New York; A. J. Morehouse, Jackson, Michigan; and several members of the Louisville Junior Astronomical Society in Kentucky. P. Seldon, New York City, had erected a battery of four all-sky cameras at Nahant, Massachusetts. One series of his pictures showed the projection of the moon's shadow cone on the overcast.

During totality, even under unbroken clouds, photometric measurements can be made of sky brightness. Two such studies were reported, in addition to A. Spitz's results on page 4 of the November issue. One was made at Salem, by G. R. Wright, of Silver Spring, Maryland. R. C. Jones set up his brightness meter on the roof of the Ambassador Hotel in Cambridge, obtaining a good series of measurements, even though a light drizzle was falling.

Other aspects of the eclipse were described in two reports. At Proctorville, Ohio, D. F. Thomas listened on the 1538-kilocycle broadcast band to determine whether distant stations could be heard while the sun was covered by the moon. The powerful commercial station KXEL, Waterloo, Iowa, was operating on a nearby frequency, and obligingly ceased transmission briefly so as not to block Mr. Thomas' incoming signals. At Spokane, Washington, B. C. Parmenter prepared a large full-disk drawing of the sun with his 14-foot spectrohelioscope. This drawing shows many prominences and a very bright region on the sun the day of the eclipse.

OCCULTATION OF REGULUS BY VENUS

On July 7, 1959, Angelo A. Bernasconi, of Saronno, Italy, observed the occultation of Regulus by Venus with a 2.4-inch refractor, 60x. With the aid of a stop watch and radio time signals, the disappearance of the star was recorded at 14:21:22 Universal time. Regulus became clearly visible again at 14:31:30.

CORRECTION

On page 633 of the September issue, in the fourth line of the caption of the light curve of V Sagittae, read "17 days" in place of "eight days."

Sky and TELESCOPE

DECEMBER, 1959

Occultation Supplement

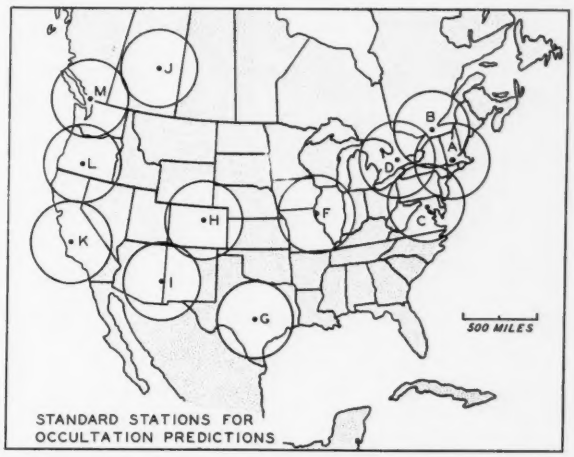
1960 Predictions for the United States and Canada

BY SPECIAL ARRANGEMENT with the Nautical Almanac Office at the Royal Greenwich Observatory, this supplement becomes a new annual feature of SKY AND TELESCOPE. As explained by Mrs. Flora McBain Sadler in her article on page 84, the *American Ephemeris* and the British *Nautical Almanac*, now identical volumes, no longer carry occultation data.

A continuation of all the predictions formerly published for the United States and Canada appears in this supplement, and the number of standard stations has been increased to 12, as shown by the map. Designated by the letters **A** to **M** (except for **E**), they are identified in the main table headings. The first five columns give the date of the occultation, the *Zodiacal Catalogue* number of the star, its magnitude, the phenomenon (*1* = disappearance, *2* = reappearance), and the age of the moon in days. Following this are given for each station the Universal time of the event, **a** and **b** factors in minutes of time, and the position angle **P** (counted eastward around the moon's limb from its north point).

Predictions are omitted in certain cases, letters indicating the reason at the standard station: *N*, no occultation; *G*, grazing occultation; *S*, sunlight interferes; *H*, below horizon or too near to it. Other omissions of occultations for which satisfactory observations are not possible are explained in Mrs. Sadler's article. On September 5th, Z.C. 3353 and 3360 are given because they are occulted during a total eclipse of the moon; the times in brackets do not come during totality, however.

The **a** and **b** factors are the changes in standard station predicted times per degree of longitude and of latitude, respectively. They enable fairly accurate computation of times for each local station (longitude Lo, latitude L) within 200 or 300 miles of a standard station (longitude LoS, latitude LS). The local station time is the standard station time plus the quantity **a**(Lo − LoS) + **b**(L − LS), due regard being given to arithmetic signs.



STANDARD STATIONS FOR OCCULTATION PREDICTIONS

On the map each station is at the center of a circle of 250-mile radius, and in this area the **a** and **b** quantities should be quite useful. Careful extrapolation for somewhat greater distances, and interpolation between the results of two stations should enable observers outside the circles to make acceptable estimates. In doubtful instances, it is well to begin observing several minutes earlier than the expected time, in the case of a disappearance picking up the star and following it to the moon's edge.

For a detailed example of the use of the occultation predictions, see the last page of this supplement.

OCCULTED STARS AND PLANETS

Z.C. No.	Name, B.D. or C.D. No.	Z.C. No.	Name, B.D. or C.D. No.	Z.C. No.	Name, B.D. or C.D. No.	Z.C. No.	Name, B.D. or C.D. No.	Z.C. No.	Name, B.D. or C.D. No.
4	80 B. Psc	675	80 Tau m.	1433	+11° 2087	2110	22 B. Lib	3019	61 B. Cap
22	− 2° 19	677	264 B. Tau	1439	18 Leo	2208	−14° 4208	3029	−16° 5690
50	44 Psc	678	81 Tau	1441	19 Leo	2247	η Lib	3066	95 B. (Cap)
55	10 Cet	680	269 B. Tau	1442	*R* Leo	2271	θ Lib	3100	−15° 5908
109	155 B. Psc	682	85 Tau	1486	*A* Leo	2280	204 B. Lib	3120	−14° 5997
155	77 Psc	685	275 B. Tau	1539	173 B. Leo	2291	49 Lib	3134	−14° 6020
202	242 B. Psc	692	α Tau	1549	48 Leo	2352	107 B. Sco	3142	−14° 6026
212	95 Psc m.	741	318 B. Tau	1550	49 Leo	2399	24 (Sco)	3149	−14° 6039
269	+ 6° 275	806	111 Tau	1573	38 (Sex)	2441	90 B. Oph	3186	−13° 6008
298	136 G. Psc	814	115 Tau	1589	56 Leo	2508	192 B. Oph	3188	λ Cap
303	39 B. (Ari)	820	117 Tau	1600	59 Leo	2531	−18° 4586	3196	151 B. Cap
308	+ 7° 324	878	130 Tau	1658	80 Leo	2578	305 B. (Oph)	3238	−11° 5756
322	64 Cet	934	+18° 1112	1712	β Vir	2596	−19° 4800	3252	37 Aqr
327	ξ1 Cet	938	+17° 1154 p.	1716	+ 1° 2624	2640	64 B. Sgr	3286	−10° 5904
360	+ 9° 321	944	124 H1. Ori	1772	η Vir	2680	95 B. Sgr	3313	192 B. Aqr
398	434 B. (Cet)	970	292 B. (Ori)	1830	− 3° 3349	2685	−18° 4986	3322	167 G. Aqr m.
401	85 (Cet)	975	+17° 1224 m.	1850	91 G. Vir	2687	−19° 5047	3333	213 B. Aqr f.
462	+11° 445	1003	21 Gem f.	1855	96 G. Vir p.	2715	89 G. Sgr	3334	67 Aqr
475	+13° 535	1011	+17° 1306	1866	44 Vir	2718	92 G. Sgr	3353	λ Aqr
516	+13° 568	1029	26 Gem	1874	− 4° 3408	2724	130 B. Sgr	3360	78 Aqr
526	+13° 579	1040	74 B. Gem m.	1875	48 Vir m.	2731	−18° 5079	3379	81 Aqr
608	179 B. Tau	1072	110 B. Gem	1891	θ Vir	2733	−19° 5182	3383	82 Aqr
618	+15° 592	1091	+17° 1518	1937	72 Vir	2745	−18° 5115	3405	282 B. Aqr
626	48 Tau	1106	λ Gem	1941	74 Vir	2764	−18° 5155	3412	φ Aqr
627	+15° 607	1141	162 B. Gem	1947	77 Vir	2773	171 B. Sgr	3430	96 Aqr
635	γ Tau	1176	+16° 1551	1951	81 Vir m.	2774	173 B. Sgr	3432	317 B. Aqr
636	55 Tau m.	1197	1 Cnc	1962	82 Vir	2787	187 B. Sgr	3461	337 B. Aqr
650	63 Tau	1198	2 B. Cnc	1994	598 B. Vir p.	2791	190 B. Sgr	3470	34 G. Psc
659	70 Tau	1210	5 Cnc	1996	600 B. Vir	2794	−19° 5317	3472	− 5° 6011
661	71 Tau	1238	+16° 1662	2016	623 B. Vir	2828	45 Sgr	3496	− 3° 5697
667	75 Tau	1257	+15° 1805	2028	96 Vir	2833	−18° 5356	3505	20 Psc
669	θ1 Tau	1284	90 B. Cnc	2032	97 Vir	2846	246 B. Sgr	3528	− 2° 6071
671	θ2 Tau	1344	177 B. Cnc	2033	ϰ Vir	2865	267 B. Sgr	4001	MERCURY
672	+15° 633 m.	1409	ξ Leo	2088	6 B. Lib	2997	41 B. Cap m.		

Date		Z.C. No.	Mag.	Ph.	Age of Moon	A MASSACHUSETTS W. 72°·500, N. 42°·500				B MONTREAL, QUE. W. 73°·575, N. 45°·505				C WASHINGTON, D.C. W. 77°·065, N. 38°·920				D TORONTO, ONT. W. 79°·400, N. 43°·663			
						U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*
					d	h m	m	m	o	h m	m	m	o	h m	m	m	o	h m	m	m	o
Jan.	4	3470	7·0	1	5·2	1 47·2	−0·9	−2·4	112	1 40·0	−0·8	−1·8	99	1 52·9	−1·4	−3·9	127	1 37·7	−1·1	−1·9	101
	5	155	6·8	1	7·2	22 59·5	−0·6	+3·5	11	23 13·1	·	·	351	22 43·9	−0·8	+3·3	16		G		
	9	636	6·9	1	11·2		G				N			23 56·7	·	·	9		N		
	10	667	5·3	1	11·4	5 52·7	−0·4	−4·4	144	5 40·9	−0·7	−3·2	131		N			5 43·5	−0·7	−4·6	144
	11	806	5·1	1	12·5		H				H				N			9 24·4	·	·	166
	16	1409	5·1	2	17·5	6 56·7	·	·	0		N			7 07·7	−1·3	−3·0	333	6 48·1	·	·	352
	23	2247	5·6	2	24·7		N				N			11 00·5	·	·	354		N		
	24	2399	5·0	2	25·6	9 53·9	−0·2	−0·8	332	9 50·6	+0·2	−1·4	343	9 53·9	−0·4	−0·2	314		H		
Feb.	2	109	6·5	1	4·7	0 53·2	−0·8	−0·9	78	0 50·1	−0·8	−0·6	67	0 52·6	−1·1	−1·2	88	0 46·0	−1·0	−0·6	71
	3	360	6·8	1	6·7	23 49·6	−1·6	+1·1	49	23 51·8	−1·4	+1·6	37	23 37·7	−1·9	+1·0	57	23 40·3	−1·5	+1·8	39
	6	618	7·2	1	8·9	4 27·8	−1·0	+0·6	41	4 29·5	−1·2	+1·5	28	4 22·2	−1·1	−0·1	58	4 20·8	−1·2	+0·7	41
	7	741	5·7	1	9·8	2 20·6	−1·9	−0·8	90	2 16·7	−1·8	−0·4	81	2 14·9	−2·2	−1·3	103	2 06·2	−2·1	−0·4	87
	8	878	5·5	1	10·8	2 22·7	−2·0	−2·1	121	2 15·5	−1·9	−1·3	111	2 22·7	−2·2	−3·5	138	2 06·3	−2·1	−1·5	118
	9	1011	7·4	1	11·8	0 41·0	−2·0	0·0	105	0 39·9	−1·8	+0·6	95	0 32·2	−2·1	−0·4	116	0 28·6	−1·7	+0·6	99
	9	1029	5·1	1	11·9	5 13·3	−1·4	−0·9	82	5 09·2	−1·5	−0·6	75	5 10·5	−1·5	−1·3	97	5 01·6	−1·7	−0·8	85
	21	2508	6·3	2	24·2		N				N			9 54·0	·	·	346		N		
Mar.	4	692	1·1	1	7·2	23 40·7	−2·1	−0·3	84	23 38·3	−1·9	+0·1	74	23 32·2	−2·4	−0·6	96	23 26·3	−2·1	+0·3	79
	5	692	1·1	2	7·2	1 08·1	−1·6	−0·8	263	1 03·3	−1·5	−1·2	272	1 01·7	−1·9	0·0	250	0 55·6	−1·8	−0·7	265
	7	970	6·5	1	9·3	3 18·4	−1·4	−0·7	76	3 15·0	−1·5	−0·4	67	3 14·9	−1·5	−1·1	91	3 07·0	−1·6	−0·6	78
	7	975	6·8	1	9·3	4 10·0	−0·7	−1·9	109	4 03·7	−0·8	−1·8	102	4 14·6	−0·7	−2·4	124	4 02·2	−0·9	−2·0	112
	8	1091	6·7	1	10·4	3 12·8	−1·5	−1·6	107	3 06·7	−1·5	−1·3	99	3 12·7	−1·5	−2·2	122	3 00·2	−1·7	−1·5	109
	8	1106	3·6	1	10·5	6 56·7	+0·3	−2·2	134	6 50·5	+0·2	−2·1	128	7 07·1	+0·5	−2·7	149	6 55·7	+0·2	−2·4	138
	8	1197	6·0	1	11·3	23 17·8	−1·6	+0·5	104		S				S				S		
	12	1549	5·2	1	14·4	3 12·1	·	·	50		N			2 51·5	−2·3	+1·5	75	2 56·6	−2·5	+3·2	56
	15	1891	4·4	1	17·4	2 33·5	−1·0	+1·9	75	2 39·2	−1·1	+2·7	63	2 24·1	−0·7	+1·2	92	2 29·8	−0·7	+1·9	76
	15	1891	4·4	2	17·4	3 26·2	−0·6	−1·1	332	3 21·7	−0·3	−1·6	343	3 25·6	−0·8	−0·4	314	3 21·5	−0·5	−0·8	329
	16	2028	6·5	2	18·5	6 38·5	−1·9	+0·1	277	6 36·9	−1·6	0·0	283	6 27·5	−2·2	+0·8	262	6 26·3	−1·8	+0·6	271
	25	4001	1·1	1	27·7	10 24·5	−0·4	+2·5	30	10 31·9	−0·4	+2·7	22		H				H		
	25	4001	1·1	2	27·7	11 11·5	−0·7	+0·8	294	11 13·0	−0·7	+0·7	301	11 05·5	−0·5	+0·9	286	11 08·3	−0·4	+0·8	297
Apr.	14	2247	5·6	2	17·9	6 07·9	−1·2	−1·0	322	6 03·8	−1·0	−1·0	328	6 04·6	−1·4	−0·5	308	5 59·1	−1·1	−0·6	317
	15	2399	5·0	2	18·9	4 35·5	−0·8	+0·4	296	4 36·1	−0·6	+0·4	303	4 29·8	−0·8	+0·8	282		H		
	17	2731	6·5	2	21·0	6 56·3	−0·8	−0·1	314	6 55·0	−0·6	−0·3	321	6 52·1	−0·9	+0·3	300	6 51·5	−0·6	+0·2	311
	21	3322	6·4	2	25·1		S				S			9 19·3	−0·7	+1·7	247		S		
	28	692	1·1	1	2·8	14 02·6	−0·1	+2·1	58	14 09·1	−0·1	+2·3	50	13 55·1	0·0	+1·9	61	14 04·9	+0·1	+2·2	48
	28	692	1·1	2	2·8	15 07·1	−1·0	+1·2	274	15 09·5	−1·0	+1·1	282	14 58·6	−0·8	+1·3	270	15 02·2	−0·8	+1·0	284
May	1	1003	7·2	1	5·1	0 26·3	−1·0	−1·3	87		S			0 26·5	−1·1	−1·6	102		S		
	1	1011	7·4	1	5·2	2 24·9	−0·2	−1·0	77	2 21·5	−0·3	−1·0	71	2 27·8	−0·3	−1·3	90	2 21·2	−0·4	−1·2	81
	10	2033	4·3	1	14·2	1 12·4	−2·0	+2·5	60	1 19·5	·	·	46	0 58·1	−1·4	+1·4	81	1 03·4	−1·5	+2·2	66
June	5	1855	7·1	1	10·6	2 54·7	−1·1	−2·2	147	2 47·2	−1·1	−2·0	142	2 59·0	−0·9	−2·9	161	2 44·7	−1·0	−2·2	152
	6	1996	6·9	1	11·7	6 07·9	−0·7	−2·3	141	6 00·5	−0·7	−2·1	135	6 13·0	−0·8	−2·6	149	6 00·1	−0·8	−2·2	138
	7	2110	6·4	1	12·6	3 12·1	−1·8	−0·5	97	3 09·0	−1·8	−0·3	92	3 05·3	−1·9	−0·6	108	2 59·2	−1·8	−0·3	101
July	3	1947	7·1	1	9·0		H				H				H			4 33·6	−0·6	−2·3	140
	13	3461	6·4	2	19·1	4 26·6	−0·6	+1·5	259	4 30·5	−0·6	+1·5	264	4 18·6	−0·5	+1·6	253		H		
	19	685	6·5	2	25·2		S				S			8 15·2	−0·3	+0·9	285	8 18·1	−0·4	+0·6	300
	19	692	1·1	1	25·3	8 47·4	+0·2	+3·1	27	8 58·0	+0·5	+3·9	15	8 38·2	+0·3	+2·7	32	8 54·5	·	·	12
	19	692	1·1	2	25·3	9 32·8	−1·4	+0·2	303	9 30·8	−1·6	−0·6	316	9 26·1	−1·1	+0·4	298	9 22·9	·	·	320
	20	806	5·1	2	26·3		S				S			8 50·0	+0·2	+2·0	236		S		
	27	1573	7·0	1	3·2		H				S			1 01·1	−0·2	−1·5	104		S		
	31	2016	6·5	1	7·2		N				N			0 56·2	·	·	41		N		
Aug.	2	2280	6·8	1	9·3	1 58·1	−1·7	+0·2	55	1 57·2	−1·6	+0·4	47	1 49·1	−2·0	+0·1	65	1 45·8	−2·0	+0·5	54
	2	2291	5·5	1	9·4	3 49·8	−1·2	−2·4	139	3 41·9	−1·1	−2·1	132	3 53·1	−1·4	−2·8	147	3 38·8	−1·3	−2·1	133
	3	2441	6·5	1	10·4	3 22·8	−1·3	−0·4	68	3 20·2	−1·2	−0·3	62	3 17·6	−1·6	−0·4	74	3 12·6	−1·5	−0·2	64
	5	2773	6·1	1	12·3		N			2 12·5	·	·	159		N				G		
	5	2774	6·3	1	12·3	1 55·3	−1·7	−0·2	119	1 53·3	−1·6	0·0	113	1 48·8	−1·6	−0·5	128	1 44·3	−1·5	+0·1	118
	15	626	6·4	2	22·5	6 19·9	−0·2	+1·6	259	6 24·3	−0·3	+1·5	266	6 13·6	−0·1	+1·5	256	6 20·3	−0·1	+1·4	267
	15	635	3·9	1	22·6	7 25·6	−0·7	+1·6	79	7 30·2	−0·6	+1·8	71	7 17·1	−0·6	+1·5	82	7 23·9	−0·4	+1·8	70
	15	635	3·9	2	22·6	8 39·0	−1·1	+1·9	248	8 43·0	−1·1	+1·6	256	8 27·4	−0·9	+2·0	244	8 33·8	−1·0	+1·6	258
	15	692	1·1	1	22·9		N				N			18 05·5	−0·6	+0·8	35	18 13·6	·	·	6
	15	692	1·1	2	22·9		N				N			18 40·7	+0·7	−2·9	321	18 22·3	·	·	350
	30	2399	5·0	1	7·7		H				H			3 15·6	−0·9	−1·6	107	3 06·5	−0·9	−1·3	95
	31	2531	7·3	1	8·7	0 59·5	−1·8	−0·6	96	0 55·9	−1·7	−0·5	91	0 53·0	−2·0	−0·6	102	0 46·4	−1·8	−0·3	93
Sept.	1	2715	6·5	1	9·7	3 53·7	·	·	158	3 39·6	−1·9	−2·8	140		N			3 33·1	−2·0	−2·6	138
	3	3019	5·9	1	11·7	0 48·6	−1·7	−0·5	131	0 46·3	−1·5	0·0	124	0 44·2	·	·	143	0 38·0	−1·3	0·0	128
	26	2352	6·7	1	5·0		H				H			0 49·1	−0·9	−0·8	77	0 43·5	−0·9	−0·6	65
	29	2828	6·0	1	8·1	1 07·4	−1·2	+0·8	38	1 09·1	−0·9	+1·1	28	0 58·1	−1·5	+0·9	43	1 00·6	−1·2	+1·5	27
	29	2833	7·0	1	8·1	2 50·5	−1·9	−3·0	135	2 41·1	−1·6	−2·1	123	2 52·4	·	·	143	2 35·0	−1·8	−1·9	121
Oct.	1	3120	7·0	1	10·1	0 47·7	−2·1	−0·2	108	0 45·4	−1·9	+0·1	101	0 38·4	−2·2	−0·2	113	0 34·2	−1·8	+0·4	101
	3	3412	4·4	1	12·2	2 37·0	−2·9	−1·3	123	2 32·1	−2·2	−0·3	111	2 28·1	·	·	127	2 19·7	−2·1	+0·1	108
	7	401	6·3	2	16·2	3 02·8	−1·7	+0·1	301	3 00·2	·	·	315	2 54·9	−1·4	+0·3	297	2 50·0	·	·	320
	9	659	6·4	2	18·2	3 38·6	−0·8	+1·0	285	3 40·4	−0·9	+0·8	294	3 31·7	−0·6	+1·0	281	3 34·3	−0·7	+0·7	295

Date	Z.C. No.	Mag.	Ph.	Age of Moon	A Massachusetts W. 72°.500, N. 42°.500				B Montreal, Que. W. 73°.575, N. 45°.505				C Washington, D.C. W. 77°.065, N. 38°.920				D Toronto, Ont. W. 79°.400, N. 43°.663			
					U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P
				d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Oct. 9	661	4·6	2	18·2	3 34·4	·	·	189	3 46·1	+0·2	+3·3	203	3 20·8	·	·	178	3 41·3	+0·2	+3·1	205
9	669	4·0	1	18·3	4 08·6	−0·8	+1·5	84	4 12·7	−0·7	+1·7	76	4 00·1	−0·7	+1·3	87	4 06·1	−0·5	+1·7	75
9	669	4·0	2	18·3	5 21·2	−1·1	+1·9	244	5 25·4	−1·1	+1·7	253	5 09·3	−0·9	+2·1	240	5 16·1	−1·0	+1·7	254
9	671	3·6	1	18·3	4 13·0	−1·1	+0·8	107	4 15·0	−0·9	+1·2	98	4 05·4	−1·1	+0·6	111	4 08·0	−0·7	+1·2	96
9	671	3·6	2	18·3	5 15·0	−0·7	+2·7	221	5 21·7	−0·9	+2·4	231	5 02·0	−0·5	+2·9	216	5 12·8	−0·7	+2·3	232
9	677	4·8	2	18·3	6 45·1	−1·9	+0·8	266	6 45·0	−1·9	+0·5	276	6 32·9	−1·8	+1·2	260	6 33·2	−1·8	+0·7	276
9	685	6·5	2	18·4	8 56·2	−2·0	+0·2	258	8 53·9	−2·0	−0·2	268	8 44·6	−2·2	+0·9	248	8 42·2	−2·1	+0·2	264
9	692	1·1	1	18·4	9 09·8	−2·0	+0·8	61	9 11·1	−1·8	+1·4	50	8 57·7	−2·2	+0·6	72	8 57·9	−1·9	+1·5	55
9	692	1·1	2	18·4	10 30·7	−1·6	−1·6	282	10 23·6	−1·5	−2·0	293	10 27·0	−1·9	−0·8	269	10 17·0	−1·8	−1·5	286
10	806	5·1	2	19·4	8 11·0	·	·	202	8 20·8	−1·6	+3·0	218		N			8 06·5	−1·3	+3·4	215
10	814	5·3	2	19·4		N				N			10 04·7	·	·	334		N		
11	934	6·4	2	20·3	5 40·4	−1·5	−0·5	313	5 35·6	·	·	329	5 35·0	−1·2	0·0	305	5 28·5	·	·	331
11	944	5·7	2	20·4	7 55·4	−1·5	+2·4	235	8 00·2	−1·5	+1·9	246	7 39·0	−1·2	+3·1	225	7 48·1	−1·3	+2·1	244
12	1072	6·2	2	21·3	6 26·1	−1·1	+0·4	297	6 25·7	−1·1	0·0	308	6 19·6	−0·9	+0·6	290	6 19·4	−1·0	+0·1	307
13	1198	6·2	2	22·5		S				S				S			10 15·0	−1·9	−1·6	316
24	2596	7·3	1	4·4	22 40·7	−1·0	+1·1	32	22 44·3	·	·	19		S				S		
25	2773	6·1	1	5·4	22 48·4	·	·	142	22 40·0	−2·0	−1·6	131	22 46·9	·	·	151		S		
25	2774	6·3	1	5·4	22 36·2	−1·9	−0·8	103	22 32·3	−1·7	−0·5	97		S				S		
26	2787	6·4	1	5·5	0 52·4	−0·7	−0·3	58	0 50·9	−0·6	−0·2	49	0 49·4	−1·0	−0·3	62	0 46·7	−0·8	0·0	48
26	2794	6·7	1	5·5		H				H			1 41·8	−1·5	−2·6	128	1 28·7	−1·2	−1·7	110
29	3238	7·0	1	8·7		H				N			4 51·7	−0·1	+1·2	24		G		
29	3353	3·8	1	9·5	23 09·4	−1·3	+1·9	45	23 13·8	−1·2	+1·9	39	22 56·6	−1·3	+1·9	49	23 03·4	−1·1	+2·1	38
30	3360	6·3	1	9·5	0 57·7	·	·	1		N			0 43·3	·	·	6		N		
30	3383	6·5	1	9·7	5 21·6	−0·6	−0·7	70	5 19·3	−0·6	−0·4	60	5 20·7	−0·9	−0·8	78	5 16·2	−0·8	−0·3	61
Nov. 6	741	5·7	2	16·7	3 10·6	−1·3	+0·6	290	3 10·6	−1·4	+0·3	301	3 02·5	−1·1	+0·8	285	3 02·3	−1·2	+0·3	303
7	878	5·5	2	17·6	2 24·7	+0·2	+2·7	219	2 32·5	0·0	+2·4	229	2 16·1	+0·4	+2·8	213	2 28·6	+0·2	+2·3	230
8	1040	6·2	2	18·8	8 22·9	−2·1	−1·0	291	8 17·0	−2·0	−1·4	301	8 14·6	−2·4	−0·2	278	8 07·1	−2·1	−0·8	295
9	1141	5·6	2	19·7	4 26·5	−0·1	+3·1	226	4 34·5	−0·3	+2·5	237	4 15·1	+0·3	+3·5	216	4 28·9	−0·1	+2·4	237
12	1486	4·6	2	23·0		S			10 48·8	−0·9	−3·5	345	10 59·8	−1·7	−1·7	316	10 47·3	−1·3	−2·2	330
21	2715	6·5	1	2·9	22 03·9	−1·0	−0·2	57	22 02·5	−0·9	0·0	49		S				S		
21	2718	6·7	1	2·9	22 36·4	−0·9	−0·7	73	22 33·5	−0·9	−0·6	65	22 33·9	−1·2	−0·6	77	22 28·9	−1·1	−0·4	64
23	3029	6·9	1	4·9	22 17·5	−1·0	+1·5	26	22 21·5	−0·6	+2·0	15		S				S		
24	3186	6·7	1	6·0	23 28·0	−2·3	−1·3	110	23 22·7	−2·0	−0·8	101	23 21·5	−2·7	−1·4	114	23 12·1	−2·1	−0·4	98
26	3333	6·8	1	7·1	1 25·9	−0·9	+0·6	42	1 27·2	−0·7	+0·9	31	1 18·7	−1·2	+0·7	46	1 20·8	−0·8	+1·2	29
26	3472	7·0	1	8·0	23 50·9	−1·4	+1·5	42	23 54·2	−1·1	+1·6	33	23 38·7	−1·5	+1·7	44	23 44·3	−1·1	+2·0	30
28	55	6·4	1	9·1	0 56·7	−2·0	+0·2	82	0 55·7	−1·8	+0·5	74	0 45·8	−2·3	+0·3	85	0 44·2	−1·8	+0·8	71
29	202	7·0	1	10·2	4 58·4	−1·3	−2·0	104	4 52·0	−1·2	−1·4	92	5 00·1	−1·7	−2·9	117	4 46·7	−1·5	−1·4	95
29	298	7·2	1	11·0	22 16·8	·	·	351		N				S				N		
29	303	6·6	1	11·0	23 24·5	−1·7	+0·7	106	23 25·5	−1·4	+1·1	98	23 14·7	−1·6	+0·6	109	23 16·0	−1·1	+1·2	95
30	308	6·7	1	11·1	0 40·1	−0·9	+2·7	28	0 48·0	−0·6	+3·1	18	0 26·4	−0·9	+2·7	31	0 39·2	−0·4	+3·4	14
30	322	5·7	1	11·2	4 01·9	−1·8	−0·5	83	3 59·2	−1·6	−0·1	73	3 54·8	−2·2	−0·6	91	3 49·1	−1·8	+0·2	73
30	327	4·5	1	11·2	5 15·1	−1·3	+0·1	58	5 14·7	−1·1	+0·5	47	5 08·6	−1·6	−0·1	68	5 06·5	−1·3	+0·6	50
Dec. 2	692	1·1	1	14·1	23 27·1	+0·1	+2·4	43	23 34·7	+0·2	+2·6	34	23 19·7	+0·2	+2·1	47	23 31·4	+0·3	+2·5	33
3	692	1·1	2	14·1	0 22·0	−0·9	+0·9	287	0 23·3	−1·0	+0·7	296	0 14·8	−0·7	+0·9	283	0 16·7	−0·8	+0·6	298
7	1210	5·9	2	18·1	2 10·6	+0·2	+2·4	234	2 17·6	0·0	+2·1	244		H			2 14·5	+0·2	+2·0	244
7	1238	6·1	2	18·4		G				N			9 27·4	−1·2	−3·7	332	9 01·6	·	·	356
9	1439	5·9	2	20·3	6 53·9	−1·3	−3·1	342		G			6 55·4	−1·5	−1·5	323	6 41·8	·	·	347
9	1441	6·4	2	20·3	8 05·8	−1·8	−0·7	300	8 01·5	−1·6	−1·0	310	7 58·2	−2·0	+0·1	286	7 53·3	−1·6	−0·4	300
9	1442	Var.	2	20·3	8 18·1	−2·1	+0·4	273	8 16·8	−1·9	+0·1	282	8 04·4	−2·3	+1·6	256	8 05·0	−1·9	+0·8	272
11	1658	6·4	2	22·4	10 55·8	·	·	241	10 56·8	−2·6	+1·0	251		N			10 35·2	·	·	230
13	1866	5·9	2	24·4	8 35·9	−1·0	+1·3	271	8 38·5	−0·8	+1·0	280	8 25·4	−1·0	+2·1	253	8 31·6	−0·7	+1·4	270
14	1994	6·5	2	25·5	10 34·6	−0·3	−1·9	344	10 27·6	·	·	357	10 36·6	−0·7	−0·9	324	10 30·4	−0·4	−1·3	339
21	3134	6·9	1	3·5	23 00·5	·	·	143	22 47·3	−1·9	−2·4	123		N			22 39·6	−2·1	−2·1	120
22	3142	6·8	1	3·5	0 10·9	+0·1	+1·3	19		H			0 06·5	−0·2	+1·0	27	0 16·3	·	·	357
22	3286	7·3	1	4·5	23 22·1	−1·4	−0·6	80	23 19·2	−1·2	−0·4	71	23 17·2	−1·7	−0·6	84	23 12·0	−1·4	−0·1	69
24	3432	6·3	1	5·6	0 30·7	−1·9	−2·1	110	0 23·8	−1·6	−1·3	98	0 29·2	−2·5	−2·7	118	0 16·2	−1·8	−1·1	96
25	22	7·3	1	6·6	0 28·6	−1·1	+1·1	37	0 31·5	−0·8	+1·5	25	0 18·9	−1·3	+1·2	42	0 23·4	−0·9	+1·8	24
27	298	7·2	1	8·7	5 43·4	−0·4	+0·1	45	5 43·9	−0·4	+0·5	34	5 41·6	−0·5	−0·2	59	5 40·4	−0·5	+0·3	42
27	398	6·7	1	9·6	23 19·6	−1·2	+2·2	47	23 25·1	−1·0	+2·4	38	23 06·3	−1·2	+2·2	50	23 15·2	−0·8	+2·6	36
27	401	6·3	1	9·6	24 06·0	·	·	10		G			23 49·6	−0·5	+3·7	15		G		
29	516	7·3	1	10·6	0 23·3	−1·2	+2·6	39	0 30·6	−0·9	+3·0	27	0 08·9	−1·1	+2·5	43	0 20·3	−0·7	+3·2	25
29	526	6·9	1	10·7	4 28·3	−1·6	−2·7	120	4 19·7	−1·6	−1·9	107	4 33·3	·	·	139	4 13·3	−1·9	−2·1	113
29	635	3·9	1	11·5	21 46·3	−0·5	+1·4	90	21 50·3	−0·4	+1·6	83		S				S		
30	659	6·4	1	11·6	1 30·6	−2·6	−1·0	119	1 26·7	−2·1	−0·1	107	1 22·9	·	·	128	1 14·6	−2·0	+0·2	106
30	667	5·3	1	11·7	3 33·7	−1·9	+0·9	60	3 35·2	−1·7	+1·4	49	3 21·1	−2·2	+0·8	70	3 22·1	−1·8	+1·6	53
30	677	4·8	1	11·7	5 02·9	−1·6	−2·6	121	4 54·4	−1·6	−1·9	109	5 07·4	·	·	140	4 48·0	−1·9	−2·2	116
30	685	6·5	1	11·8	6 53·3	−0·7	−2·0	107	6 47·0	−0·8	−1·7	98	6 58·3	−0·7	−2·7	123	6 45·2	−1·0	−2·0	107
30	692	1·1	1	11·9	8 07·2	−0·4	−0·8	72	8 04·4	−0·5	−0·7	64	8 08·8	−0·4	−1·1	86	8 02·8	−0·6	−0·9	73
30	692	1·1	2	11·9	9 05·7	+0·2	−1·5	282	9 00·8	+0·2	−1·8	290	9 11·0	0·0	−1·2	269	9 04·6	0·0	−1·6	280
31	814	5·3	1	12·9	8 35·2	−0·8	−0·1	52	8 34·4	−0·9	+0·3	42	8 32·8	−0·8	−0·6	68	8 28·9	−1·0	−0·2	54

Date	Z.C. No.	Mag.	Ph.	Age of Moon	F ILLINOIS W. 91°000, N. 40°000				G TEXAS W. 98°000, N. 31°000				H DENVER, COLO. W. 104°950, N. 39°677				I N. MEX.–ARIZ. W. 109°000, N. 34°000			
					U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P
				d	h m	m	m	o	h m	m	m	o	h m	m	m	o	h m	m	m	o
Jan. 3	3334	6·3	1	4·3	2 25·0	−0·8	−1·9	105		N			2 11·1	−1·3	−1·2	92	2 13·8	−1·8	−2·0	108
4	3470	7·0	1	5·2	1 27·9	−1·8	−1·8	103		G			1 01·3	−2·0	−0·5	86	0 55·4	−2·7	−0·8	98
5	50	6·0	1	6·3		N			3 59·5	−0·5	+2·5	17		N				N		
10	650	5·7	1	11·3		N			1 46·6	·	·	3		N				N		
10	692	1·1	1	11·6	9 45·0	+0·6	−2·7	139		N			9 57·4	·	·	165		N		
10	692	1·1	2	11·6		H				N			10 13·0	·	·	194		N		
11	814	5·3	1	12·6		N				H				G			10 37·4	−0·8	+0·2	52
16	1409	5·1	2	17·5	6 44·2	−1·6	−1·8	321	6 38·6	−2·2	0·0	284	6 22·3	−1·5	−0·8	312	6 17·7	−1·6	+0·1	290
20	1850	6·5	2	21·6		N			7 27·6	−0·5	−1·1	325		G			7 20·6	−0·2	−1·1	329
22	2110	6·4	2	23·7	11 56·8	−1·2	−1·3	326	11 53·2	−1·9	−0·3	292	11 40·0	−1·2	−0·3	306	11 34·5	−1·5	+0·3	286
23	2247	5·6	2	24·7	10 53·7	−0·5	−1·0	331	10 51·5	−1·0	+0·1	294	10 46·9	−0·4	−0·1	311	10 43·6	−0·6	+0·5	289
Feb. 1	4	6·3	1	3·8		H				N			2 32·3	−0·9	−2·0	104	2 43·8	·	·	132
2	109	6·5	1	4·7	0 33·1	−1·6	−0·4	75		S				S				S		
5	475	7·4	1	7·8		N			1 20·0	·	·	13		N				N		
6	618	7·2	1	8·9	4 03·4	−1·6	+0·1	61	3 54·6	−2·1	−1·1	94	3 37·5	−2·1	+0·6	63	3 26·9	−2·5	−0·1	82
6	627	6·8	1	9·0		N				H			7 41·6	·	·	17	7 31·4	−0·8	+0·3	52
7	741	5·7	1	9·8	1 41·3	−2·4	−0·2	96	1 30·6	−3·4	−2·3	126	1 09·9	−2·0	+0·9	87		S		
8	878	5·5	1	10·8	1 45·3	−2·5	−1·9	129		N			1 12·7	−2·1	−0·4	119	1 09·9	·	·	140
9	1011	7·4	1	11·8	0 08·0	−1·4	+0·7	103		S				S				S		
9	1029	5·1	1	11·9	4 44·2	−2·0	−1·2	105	4 49·8	−2·0	−3·9	144	4 14·4	−2·3	−0·9	111	4 13·9	−2·5	−2·6	134
10	1141	5·6	1	12·9		N			3 30·1	·	·	35		N				N		
15	1716	6·4	2	18·1		N			10 35·2	−1·0	−3·0	335	10 01·6	−0·5	−3·6	352	10 13·6	−1·4	−2·3	326
17	1962	5·2	2	20·2		S				N			13 04·0	·	·	228		N		
21	2508	6·3	2	24·2	9 49·5	−0·3	−0·7	326	9 46·6	−0·7	+0·4	289		H				H		
22	2680	5·8	2	25·3		S			12 12·4	−1·4	+0·2	291	12 05·8	−0·8	0·0	308	12 01·0	−0·9	+0·5	289
Mar. 4	692	1·1	1	7·2	22 59·3	−2·2	+0·7	84	22 39·7	−2·8	−0·3	107	22 32·0	−1·6	+1·6	72	22 17·2	−1·7	+1·3	84
4	692	1·1	2	7·2	24 32·8	−2·2	+0·4	254	24 03·2	−2·3	+2·7	224	24 01·3	−2·2	+0·8	260	23 45·3	−2·1	+1·7	246
7	970	6·5	1	9·3	2 48·7	−2·0	−1·0	97	2 50·2	−2·3	−3·2	134	2 18·1	−2·3	−0·6	103	2 14·6	−2·7	−1·9	124
7	975	6·8	1	9·3	3 59·5	−1·1	−3·0	135		N			3 42·8	·	·	150		N		
8	1091	6·7	1	10·4	2 46·1	−1·9	−2·3	130		N			2 17·9	−2·2	−2·3	137		N		
8	1106	3·6	1	10·5	7 10·9	+0·7	−4·3	166		N				N				N		
10	1344	6·8	1	12·5		G			6 53·3	−2·0	−0·6	82	6 36·5	−2·5	+0·5	64	6 27·2	−2·3	−0·6	89
12	1549	5·2	1	14·4	2 26·8	−1·5	+1·5	82	2 11·3	−1·2	−0·1	117	2 09·8	−0·9	+1·4	88	2 01·5	−0·7	+0·5	108
15	1891	4·4	2	17·4	3 17·1	−0·4	+0·1	306	3 09·2	−0·5	+1·0	271		H				H		
16	2028	6·5	2	18·5	5 59·3	−2·1	+2·5	242		N				N				N		
16	2033	4·3	1	18·6	7 13·8	·	·	56	6 47·1	−1·7	+0·4	100	6 43·7	−1·5	+1·4	81	6 33·1	−1·1	+0·5	105
16	2033	4·3	2	18·6	7 55·5	·	·	352	8 03·6	−1·6	−1·1	311	7 45·4	−0·9	−1·1	326	7 44·9	−1·4	−0·4	304
Apr. 1	659	6·4	1	4·8		H				N			4 11·5	+0·5	−4·1	148		N		
5	1176	7·4	1	8·8		N				G				N			4 20·6	·	·	43
14	2247	5·6	2	17·9	5 46·4	−1·1	+0·2	295	5 31·0	−1·5	+1·3	260	5 32·0	−0·9	+0·9	278	5 21·4	−1·0	+1·6	255
16	2578	6·4	2	20·1		N			10 45·0	−2·3	−2·1	321		N			10 17·9	−1·6	−1·7	326
20	3188	5·4	2	24·1	9 42·1	−0·7	+0·6	295		H				H				H		
28	692	1·1	1	2·8	13 59·9	+0·4	+2·0	47		H				H				H		
28	692	1·1	2	2·8	14 51·4	−0·4	+0·9	287	14 41·4	0·0	+1·0	271	14 47·2	−0·1	+0·5	300		H		
29	741	5·7	1	3·2		H				H			3 01·3	−0·3	−0·9	75	3 06·2	−0·2	−1·3	95
30	878	5·5	1	4·2	3 06·4	0·0	−1·4	98	3 23·0	+0·3	−2·3	131	3 05·0	−0·3	−1·9	111	3 16·9	−0·1	−2·6	134
May 1	1011	7·4	1	5·2	2 20·1	−0·6	−1·6	101	2 35·0	−0·4	−2·7	135		S				S		
3	1257	7·5	1	7·3		H				H			6 02·2	−0·2	−1·4	98	6 10·4	−0·1	−1·7	114
15	2865	5·9	2	19·5	9 33·8	·	·	194		N			9 08·1	·	·	195		N		
June 1	1433	6·8	1	6·7		H				H			5 24·1	−0·2	−1·5	101	5 32·4	−0·2	−1·7	115
2	1539	7·4	1	7·6	4 56·1	−0·1	−2·2	137	5 19·9	+0·2	−3·5	168	4 53·8	−0·3	−2·7	149	5 10·7	+0·1	−3·8	171
5	1855	7·1	1	10·6	2 48·4	·	·	186		N				N				N		
5	1874	7·5	1	10·7	6 49·8	−0·6	−0·6	64	6 51·8	−0·9	−1·0	88	6 37·1	−1·2	−0·7	70	6 36·2	−1·4	−0·9	86
6	1996	6·9	1	11·7	5 57·2	−1·1	−2·4	149		N			5 42·5	−1·1	−2·7	161		N		
7	2110	6·4	1	12·6	2 40·9	−1·5	−0·4	121	2 41·6	−0·8	−2·1	158		S				S		
8	2291	5·5	1	13·8		H			9 21·1	−1·0	−1·1	97	9 06·4	−1·1	−0·7	73	9 05·5	−1·3	−0·8	84
15	3383	6·5	2	20·9	8 09·5	−1·0	+2·1	228	7 41·6	−0·8	+2·8	208	7 57·2	−0·6	+2·1	230		H		
July 1	1716	6·4	1	7·0		H				H			5 03·2	−0·2	−2·8	157	5 22·7	·	·	182
3	1947	7·1	1	9·0	4 34·0	−0·8	−2·6	149		G			4 21·6	−1·0	−2·8	158	4 40·6	·	·	186
3	1951	7·1	1	9·1		H				H			6 31·7	−0·6	−2·1	130	6 41·9	−0·7	−2·5	144
5	2208	7·4	1	11·1	6 04·6	−1·1	−1·3	96	6 08·0	−1·5	−1·5	114	5 46·4	−1·6	−1·0	96	5 45·5	−1·8	−1·2	108
16	322	5·7	2	22·3		S			10 12·2	−0·6	+3·1	206	10 27·7	−1·0	+2·0	237	10 12·1	−0·7	+2·2	228
16	327	4·5	1	22·4		S			10 19·1	−1·7	+1·2	84	10 24·8	−0·9	+2·1	56	10 10·0	−0·9	+1·8	64
16	327	4·5	2	22·4		S				S				S			11 27·0	−1·5	+1·7	247
19	692	1·1	1	25·3	8 50·5	·	·	6		H				N				N		
19	692	1·1	2	25·3	9 11·0	·	·	326	9 10·1	−0·2	+0·1	299		N				N		
31	2032	7·3	1	7·4		H				H			5 06·8	−0·5	0·0	51	5 05·5	−0·8	−0·4	68
31	2033	4·3	1	7·4		H				H				H			5 29·9	−0·8	−2·7	148
Aug. 2	2291	5·5	1	9·4	3 29·5	−1·6	−2·1	140		G			3 07·0	−1·6	−1·9	145	3 15·4	·	·	167
3	2441	6·5	1	10·4	2 51·8	−2·0	+0·2	72	2 35·5	−2·3	−0·1	95		S				S		

Date	Z.C. No.	Mag.	Ph.	Age of Moon	F ILLINOIS W. 91°·000, N. 40°·000				G TEXAS W. 98°·000, N. 31°·000				H DENVER, COLO. W. 104°·950, N. 39°·677				I N. MEX.–ARIZ. W. 109°·000, N. 34°·000			
					U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*
				d	h m	m	m	o	h m	m	m	o	h m	m	m	o	h m	m	m	o
Aug. 9	3412	4·4	1	16·6		G				N			6 49·2	−2·0	+0·2	113	6 42·1	·	·	127
9	3412	4·4	2	16·6		G				N			7 41·6	−1·0	+2·6	199	7 20·3	·	·	186
9	3430	5·7	2	16·7		S				S				S			11 25·8	−1·6	0·0	249
13	401	6·3	2	20·6	9 38·8	−2·0	+0·9	266	9 14·8	−1·6	+1·5	252	9 12·9	−1·7	+0·7	284	9 01·9	−1·4	+1·0	274
15	635	3·9	1	22·6	7 15·1	0·0	+1·7	67		H				H				H		
15	635	3·9	2	22·6	8 18·8	−0·6	+1·5	261	8 02·0	−0·2	+1·6	247	8 12·7	−0·2	+1·2	273		H		
15	659	6·4	2	22·7		S				S				S			11 24·8	−1·3	+2·0	241
15	692	1·1	1	22·9	17 56·3	−0·9	+0·3	47	17 53·6	−0·9	−0·8	83	17 41·9	−1·3	−0·1	59	17 38·8	−1·4	−0·7	81
15	692	1·1	2	22·9	18 44·7	+0·2	−2·5	309	19 01·0	−0·2	−1·1	273	18 45·1	−0·3	−2·2	295	18 53·0	−0·6	−1·3	274
29	2247	5·6	1	6·7	3 15·4	−1·1	−2·7	145		N			2 57·7	−1·5	−2·3	141	3 07·1	−1·7	−3·5	158
30	2399	5·0	1	7·7	2 57·9	−1·4	−1·2	97	2 58·1	−1·9	−1·5	114	2 35·5	−1·8	−0·7	95	2 32·0	−2·1	−0·9	107
Sept. 1	2715	6·5	1	9·7	3 16·3	−2·3	−2·2	137		N			2 46·2	−2·0	−1·2	132	2 47·8	·	·	151
1	2718	6·7	1	9·8		N				N			3 39·3	·	·	150		N		
1	2731	6·5	1	9·8		H			6 21·2	−0·4	+0·7	43		N			6 25·8	·	·	5
1	2733	6·4	1	9·9		N				N			6 34·3	·	·	148		N		
5	3360	6·3	1	14·0	10 20·3	−0·8	−1·8	105		N			10 06·5	−1·2	−1·2	91	10 08·7	−1·8	−1·8	107
5	3360	6·3	2	14·0		H				N			11 05·5	−0·4	+0·4	222	10 59·2	−0·3	+1·5	204
11	608	6·0	2	20·1		S				N			11 26·3	−1·8	+2·2	226	11 03·3	−1·4	+3·6	209
12	741	5·7	2	21·1		S			11 08·4	−2·7	+0·1	275	10 39·5	·	·	322	10 38·1	−2·6	−0·8	300
13	878	5·5	2	22·1	10 57·1	−1·8	+2·2	237	10 17·7	−0·7	+4·6	206	10 34·7	−1·3	+2·0	247	10 17·4	−0·9	+2·5	233
25	2208	7·4	1	4·1		N				N			1 48·0	·	·	176		N		
26	2352	6·7	1	5·0	0 32·1	−1·5	−0·4	69		S				S				S		
27	2508	6·3	1	6·1		N			2 18·7	−1·0	+1·4	37		N				G		
28	2680	5·8	1	7·2		H				H				N			5 17·3	·	·	6
28	2685	7·0	1	7·2		H				H				H			5 22·0	−0·6	−0·5	72
29	2828	6·0	1	8·1	0 37·1	−1·7	+2·1	30		S				S				S		
29	2833	7·0	1	8·1	2 18·1	−2·2	−1·4	117	2 18·0	·	·	140	1 48·1	−2·1	−0·5	108	1 42·5	−2·4	−0·9	120
29	2846	6·9	1	8·2	3 54·3	−1·4	−1·4	104	3 57·1	−2·3	−2·2	123	3 32·0	−1·8	−0·7	90	3 28·1	−2·2	−0·8	100
Oct. 3	3412	4·4	1	12·2	1 56·1	−1·7	+0·6	105	1 42·9	−1·8	−0·7	126	1 37·3	−1·0	+1·0	98	1 29·0	−0·9	+0·5	111
7	401	6·3	2	16·2	2 34·4	·	·	328	2 33·8	−0·4	+0·2	297		N				H		
9	659	6·4	2	18·2	3 26·0	−0·3	+0·5	298		H				H				H		
9	661	4·6	2	18·2	3 34·7	+0·4	+2·7	208		N				H				H		
9	669	4·0	1	18·3	3 56·5	−0·1	+1·6	72		H				H				H		
9	669	4·0	2	18·3	5 00·7	−0·6	+1·6	257	4 42·9	−0·2	+1·7	243	4 54·2	−0·3	+1·3	270	4 46·3	0·0	+1·3	260
9	671	3·6	1	18·3	3 57·7	−0·3	+1·2	94		H				H				H		
9	671	3·6	2	18·3	4 58·4	−0·4	+2·1	236	4 37·4	+0·2	+2·4	220	4 54·6	−0·1	+1·7	248	4 44·9	+0·2	+1·7	239
9	677	4·8	2	18·3	6 11·3	−1·5	+0·9	279	5 52·9	−1·0	+1·3	263	5 53·6	−1·1	+0·5	296	5 46·4	−0·7	+0·7	284
9	685	6·5	2	18·4	8 16·0	−2·0	+0·9	261	7 49·5	−1·7	+1·9	242	7 49·3	−1·7	+0·8	275	7 36·8	−1·5	+1·2	264
9	692	1·1	1	18·4	8 30·2	−1·8	+1·8	59	8 03·0	−2·1	+1·2	79	8 08·7	−1·1	+2·7	45	7 50·3	−1·1	+2·2	57
9	692	1·1	2	18·4	9 56·5	−2·3	−0·5	276	9 36·5	−2·5	+1·2	249	9 23·3	−2·4	−0·2	285	9 12·6	−2·3	+0·6	270
10	806	5·1	2	19·4	7 40·9	−0·8	+3·6	213		N			7 29·9	−0·6	+2·6	229	7 12·5	−0·1	+3·1	216
10	814	5·3	2	19·4		N			9 31·4	−3·1	−1·5	301		N				G		
11	934	6·4	2	20·3	5 17·2	·	·	335		H				N				H		
11	944	5·7	2	20·4	7 27·3	−0·8	+2·2	242	7 00·5	−0·1	+3·0	220	7 17·5	−0·5	+1·7	255	7 05·9	−0·1	+1·9	243
12	1072	6·2	2	21·3	6 09·9	−0·6	+0·1	307		H				H				H		
13	1198	6·2	2	22·5	9 57·1	−1·8	−0·5	303	9 43·1	−1·5	+0·8	275	9 35·8	−1·3	−0·4	310	9 30·8	−1·1	+0·3	292
13	1210	5·9	2	22·5		S				S			11 33·8	−2·0	−1·2	310	11 28·7	−2·0	0·0	289
26	2787	6·4	1	5·5	0 33·7	−1·2	+0·5	45	0 17·2	−2·0	+0·5	62		S				S		
26	2794	6·7	1	5·5	1 17·5	−1·7	−1·4	107	1 18·2	−2·6	−2·2	125	0 52·2	−2·0	−0·6	95		S		
28	3100	6·4	1	7·7		N				N			4 03·4	−2·2	−2·3	120	4 11·2	·	·	142
29	3238	7·0	1	8·7		G			4 32·6	−0·6	+1·8	25		N				N		
30	3379	6·4	1	9·7		N				N			3 52·3	−3·0	−1·7	118		G		
30	3383	6·5	1	9·7	5 05·9	−1·1	0·0	60	4 56·3	−1·9	−0·2	79	4 48·5	−1·3	+0·9	44	4 37·3	−1·7	+0·9	54
31	3528	7·5	1	10·8	7 49·0	−0·6	−0·7	74	7 53·2	−1·1	−1·6	103	7 38·1	−1·0	−0·3	65	7 35·8	−1·4	−0·6	81
Nov. 6	741	5·7	2	16·7	2 49·6	−0·9	+0·1	307	2 42·5	−0·3	+0·5	288		H				H		
8	1040	6·2	2	18·8	7 43·9	−2·0	+0·2	286	7 23·5	−1·7	+1·4	260	7 19·1	−1·5	+0·2	294	7 10·4	−1·3	+0·8	280
9	1141	5·6	2	19·7	4 21·7	+0·3	+2·1	236		H				H				H		
12	1486	4·6	2	23·0	10 34·8	−1·6	−0·7	308	10 22·1	−1·8	+0·9	273	10 15·1	−1·2	0·0	302	10 08·4	−1·1	+0·7	281
13	1589	6·0	2	24·0	10 43·3	−1·8	+2·2	251		N			10 22·8	−1·0	+2·9	242		N		
14	1712	3·8	1	25·1		S				S				S			13 16·0	−1·2	−1·7	147
21	2724	6·6	1	3·0	23 26·9	·	·	147		N				S				S		
22	2733	6·4	1	3·0		H			0 58·4	−0·9	−0·7	82	0 49·6	−0·7	0·0	51	0 45·8	−1·1	0·0	62
26	3333	6·8	1	7·1	1 04·7	−0·9	+2·0	22	0 38·0	−1·6	+2·0	37		G				S		
26	3353	3·8	1	7·2		H				H			6 10·3	−0·5	−1·0	82	6 14·6	−0·8	−1·5	99
26	3472	7·0	1	8·0	23 23·4	−1·0	+2·6	23		S				S				S		
27	3496	7·2	1	8·2		H			6 22·4	−0·6	−0·5	74	6 18·7	−0·5	+0·6	38	6 13·8	−0·8	+0·2	55
28	55	6·4	1	9·1	0 20·0	−1·6	+1·5	65		S				S				S		
29	202	7·0	1	10·2	4 30·4	−2·1	−1·1	97	4 29·8	·	·	128	3 59·8	−2·2	+0·3	80	3 48·9	−2·7	+0·1	91
29	212	7·3	1	10·3	7 40·1	−0·5	−0·6	70	7 45·0	−0·9	−1·7	103	7 29·6	−1·0	−0·4	68	7 28·6	−1·3	−0·9	86
30	308	6·7	1	11·1	0 24·3	·	·	4		S				N				S		

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				d	h m	m	m	o	h m	m	m	o	h m	m	m	o	h m	m	m	o
Nov. 30	322	5·7	1	11·2	3 24·8	−2·0	+0·8	71	3 02·2	−2·6	+0·6	87	2 59·8	−1·5	+1·9	54	2 43·4	−1·5	+1·7	63
30	327	4·5	1	11·2	4 45·8	−1·7	+1·0	53	4 23·7	−2·4	+0·7	73	4 22·9	−1·4	+2·2	37	4 04·7	−1·7	+2·0	49
Dec. 2	692	1·1	1	14·1	23 27·7	+0·6	+2·4	30		H				H				N		
3	692	1·1	2	14·1	0 07·5	−0·4	+0·4	302	0 01·3	0·0	+0·6	284	0 02·9	−0·2	−0·4	318		N		
7	1238	6·1	2	18·4	9 01·9	−1·8	−2·7	321	8 59·4	−2·7	−0·5	284	8 34·8	−2·0	−1·6	314	8 31·2	−2·2	−0·3	292
9	1439	5·9	2	20·3	6 36·2	−1·1	−1·3	328	6 33·2	−0·9	+0·2	294	6 24·1	−0·8	−1·4	333	6 25·7	−0·5	−0·3	310
9	1441	6·4	2	20·3	7 34·7	−1·4	+0·6	284	7 13·8	−1·1	+2·1	251	7 18·6	−0·8	+0·8	284	7 09·4	−0·6	+1·4	266
9	1442	Var.	2	20·3	7 39·5	−1·5	+2·0	254		N			7 22·7	−0·8	+2·1	253	7 05·0	−0·3	+3·5	229
10	1550	5·8	2	21·4		N			6 57·8	·	·	354		N				N		
12	1772	4·0	1	23·6		S				S			13 17·9	−1·1	−2·3	156		G		
13	1875	6·5	2	24·5		N			10 02·3	−0·3	−2·3	343		N			9 53·8	0·0	−2·7	350
14	1994	6·5	2	25·5	10 27·3	−0·5	−0·2	312	10 20·2	−0·7	+0·8	276		H				H		
21	2997	7·1	1	2·6		H				H				H			2 03·9	−0·9	−1·4	100
22	3149	7·1	1	3·6		N				N			0 35·2	·	·	139		N		
23	3432	6·3	1	5·6	23 55·6	−2·2	−0·3	90		S				S				S		
25	22	7·3	1	6·6	0 05·0	−0·8	+2·7	16		S				N				S		
27	298	7·2	1	8·7	5 31·6	−0·9	0·0	55	5 26·6	−1·4	−0·8	85	5 15·7	−1·3	+0·6	51	5 07·5	−1·8	+0·1	68
27	308	6·7	1	8·8		H				H			7 54·7	−0·4	+0·4	42	7 52·4	−0·5	−0·2	64
29	516	7·3	1	10·6	0 02·6	−0·2	+3·6	18		S				G				S		
29	526	6·9	1	10·7	3 55·0	−2·7	−2·5	121		N			3 17·3	−2·6	−0·3	105	3 10·3	−3·4	−1·6	121
30	659	6·4	1	11·6	0 51·6	−1·6	+0·7	103	0 37·5	−1·9	−0·5	122	0 35·2	−0·7	+1·4	87		S		
30	667	5·3	1	11·7	2 54·7	−1·7	+2·0	55	2 26·7	−2·0	+1·4	75	2 34·7	−1·0	+2·8	40	2 16·0	−1·0	+2·3	52
30	677	4·8	1	11·7	4 30·8	−2·7	−2·9	128		N			3 53·2	−2·6	−0·9	115	3 51·2	·	·	136
30	685	6·5	1	11·8	6 40·4	−1·4	−3·1	126		N			6 15·8	−2·3	−3·2	128		N		
30	692	1·1	1	11·9	7 58·1	−0·9	−1·4	92	8 09·8	−0·9	−3·1	130	7 41·7	−1·5	−1·5	99	7 46·7	−1·7	−2·7	122
30	692	1·1	2	11·9	9 07·0	−0·4	−1·0	261	9 03·8	−1·2	+1·0	223	8 56·9	−1·0	−0·6	251	8 51·5	−1·5	+0·9	227
31	814	5·3	1	12·9	8 17·8	−1·3	−0·7	76	8 19·6	−1·4	−1·9	111	7 56·5	−1·8	−0·7	85	7 55·1	−2·0	−1·6	106

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				d	h m	m	m	o	h m	m	m	o	h m	m	m	o	h m	m	m	o
Jan. 2	3188	5·4	1	3·2	0 13·9	−1·3	−0·8	88		S				S				S		
3	3334	6·3	1	4·3	1 56·1	−0·7	+0·1	44	1 50·8	−1·9	−0·6	85	1 47·5	−1·4	0·0	65	1 46·6	−1·0	+0·5	45
4	3470	7·0	1	5·2	0 53·3	−1·0	+0·8	42		S				S				S		
10	667	5·3	1	11·4	4 26·4	−1·7	−0·3	101		N			4 22·7	·	·	139	4 09·1	−1·9	−0·1	107
10	692	1·1	1	11·6	9 12·8	−0·4	−2·2	113		N				N			9 18·8	−0·5	−3·2	133
10	692	1·1	2	11·6	10 12·1	−0·4	−0·9	242		N				N			10 08·0	−0·9	+0·2	222
11	806	5·1	1	12·5	8 52·5	·	·	162		N				N				N		
11	814	5·3	1	12·6		N			10 27·0	−1·2	0·0	58	10 29·9	·	·	30		N		
16	1409	5·1	2	17·5		N			6 03·1	−1·1	+0·1	296	6 00·4	−1·0	−0·7	321		G		
22	2110	6·4	2	23·7	11 28·6	−0·3	−0·6	336	11 21·2	−1·1	+0·8	277	11 24·2	−0·8	+0·4	296	11 25·0	−0·5	+0·2	313
23	2271	4·3	1	24·8		S				N				S			15 03·8	−0·9	−1·1	155
Feb. 1	4	6·3	1	3·8	2 11·6	−0·7	−0·3	54	2 19·7	−1·8	−2·0	107	2 09·7	−1·4	−0·8	82	2 04·0	−1·0	−0·1	59
3	269	7·3	1	5·9	5 11·9	−0·4	−1·2	76		N			5 26·6	−0·7	−2·5	114	5 11·5	−0·7	−1·5	88
6	618	7·2	1	8·9		N			3 00·7	−2·3	+1·1	69	3 09·1	−1·8	+2·1	46	3 28·9	·	·	11
6	627	6·8	1	9·0		N			7 20·9	−1·2	+0·3	53	7 26·3	·	·	24		N		
7	741	5·7	1	9·8	1 24·9	−0·9	+2·9	39		S				S				S		
8	878	5·5	1	10·8	1 15·1	−0·9	+1·8	72		S				S				S		
9	1029	5·1	1	11·9	4 04·1	−1·5	+1·5	65	3 42·8	−2·3	−1·0	123	3 39·7	−1·8	+0·5	99	3 43·4	−1·4	+1·5	76
15	1716	6·4	2	18·1		N			9 52·9	−1·6	−1·5	315	9 40·3	−1·1	−2·0	333	9 21·7	·	·	357
17	1962	5·2	2	20·2	12 48·2	−1·6	−0·4	254		N				N			12 27·8	·	·	233
18	2088	6·2	2	21·3	13 27·8	−1·3	−1·0	296	13 26·8	−2·4	0·0	260	13 23·3	−2·0	−0·4	274	13 16·6	−1·5	−0·5	284
Mar. 4	692	1·1	1	7·2	22 59·6	−0·4	+4·0	20	22 06·7	−0·9	+1·9	65	22 20·7	−0·6	+2·6	47	22 41·4	−0·1	+3·7	22
4	692	1·1	2	7·2	23 42·1	−2·1	−1·6	315	23 26·6	−1·8	+1·2	263	23 30·2	−1·9	+0·5	284	23 26·1	−2·0	−0·7	311
7	970	6·5	1	9·3	2 11·6	−1·5	+1·9	56		S				S				S		
7	975	6·8	1	9·3	3 00·8	−1·6	−0·5	100		N			3 00·7	−2·2	−3·0	141	2 45·7	−1·8	−0·5	112
7	1003	7·2	1	9·6		N			9 16·8	·	·	26		N				N		
8	1091	6·7	1	10·4	1 58·6	−1·4	+0·9	89		S				S				S		
8	1106	3·6	1	10·5	6 21·6	−0·6	−3·0	145		N				N				G		
10	1344	6·8	1	12·5		N			5 59·8	−2·4	−0·4	96	5 58·0	−2·4	+0·6	76	6 03·2	·	·	48
12	1549	5·2	1	14·4		N				S				S			2 23·4	−0·2	+4·1	44
16	2033	4·3	1	18·6		N			6 24·7	−0·6	+0·5	110	6 29·8	−0·7	+1·3	90		H		
16	2033	4·3	2	18·6		N			7 31·4	−1·0	+0·1	296	7 30·3	−0·7	−0·2	314	7 26·0	−0·3	−0·8	336
20	2640	6·1	2	22·8		N			11 50·2	·	·	344		N				N		
Apr. 1	659	6·4	1	4·8	3 33·0	−0·5	−2·0	104		N			4 02·9	·	·	154	3 36·1	−0·7	−2·7	122
1	667	5·3	1	4·9		N			5 26·1	−0·3	−0·5	68	5 23·8	−0·6	0·0	47	5 27·2	·	·	17

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					U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*
				d	h m	m	m	o	h m	m	m	o	h m	m	m	o	h m	m	m	o
Apr. 1	669	4·0	1	4·9	5 06·3	0·0	−2·0	110		N			5 40·3	·	·	160	5 16·0	0·0	−2·7	129
1	671	3·6	1	4·9	5 16·6	+0·3	−2·9	136		N				N				N		
1	672	6·6	1	4·9	5 19·9	−0·2	−1·0	64	5 43·7	+0·2	−1·9	117	5 32·6	−0·1	−1·5	98	5 22·3	−0·3	−1·3	81
1	677	4·8	1	4·9		H				H				H			6 09·2	0·0	−1·1	77
1	680	6·7	1	4·9		H				H				H			6 14·7	0·0	−1·4	88
3	938	7·2	1	6·9	6 56·3	+0·2	−2·2	124		N			7 33·0	·	·	173	7 08·7	+0·3	−2·8	143
5	1176	7·4	1	8·8		N			3 49·2	−3·2	+2·1	53		N				N		
16	2578	6·4	2	20·1		N			10 01·1	−1·1	−0·9	321	9 50·2	·	·	347		N		
17	2764	6·3	2	21·2		S			11 40·6	−1·9	+0·4	276	11 41·2	−1·6	+0·3	289	11 39·8	−1·3	+0·2	301
30	878	5·5	1	4·2		S			3 08·8	−0·4	−3·3	140		S				S		
May 1	1029	5·1	1	5·3	5 31·0	−0·7	+0·2	33	5 40·6	−0·2	−1·1	89	5 33·5	−0·4	−1·0	74	5 26·5	−0·6	−0·7	58
3	1257	7·5	1	7·3	5 39·1	−0·6	−1·4	78	6 04·1	−0·4	−2·0	120	5 51·5	−0·6	−1·8	107	5 38·3	−0·8	−1·6	94
15	2865	5·9	2	19·5	9 26·7	−1·2	+1·5	228		N			8 47·2	·	·	192	9 06·5	−1·3	+2·3	216
June 1	1433	6·8	1	6·7	4 59·8	−0·6	−1·5	83	5 25·1	−0·5	−1·9	120	5 12·5	−0·7	−1·8	108	4 59·1	−0·8	−1·6	97
2	1539	7·4	1	7·6		S			5 05·7	·	·	185	4 39·2	−0·4	−3·2	161		S		
2	1549	5·2	1	7·7	6 43·3	−0·4	−1·1	57	7 01·6	−0·3	−1·3	95	6 52·7	−0·5	−1·3	83	6 42·9	−0·6	−1·2	71
5	1874	7·5	1	10·7	6 22·1	·	·	39	6 16·0	−1·9	−0·9	90	6 09·5	−1·9	−0·5	77	6 03·2	−1·9	−0·1	63
6	1996	6·9	1	11·7	5 08·2	−1·0	−1·2	140		N			5 21·8	·	·	178	5 03·9	−0·8	−1·6	158
8	2291	5·5	1	13·8	8 52·6	−0·9	−0·1	41	8 47·2	−1·8	−0·4	79	8 43·7	−1·6	−0·2	64	8 40·4	−1·5	+0·1	50
July 1	1716	6·4	1	7·0		S			5 14·3	·	·	186	4 49·2	−0·4	−3·0	162		S		
2	1830	6·8	1	8·1	5 52·1	−0·3	−2·7	166		N				N			6 01·7	·	·	183
3	1951	7·1	1	9·1	6 00·4	−0·7	−1·7	110	6 28·0	−1·0	−2·4	140	6 13·1	−1·0	−1·9	127	5 58·3	−1·0	−1·7	117
5	2208	7·4	1	11·1	5 24·4	−1·4	−0·4	76	5 22·2	−2·0	−0·9	109	5 16·0	−1·8	−0·5	97	5 10·3	−1·6	−0·1	87
16	322	5·7	2	22·3		S			10 09·0	−0·5	+1·8	243	10 19·7	−0·6	+1·7	257	10 29·6	−0·6	+1·5	270
16	327	4·5	1	22·4		S			10 07·2	−0·4	+2·1	49	10 22·2	−0·2	+2·6	34	10 41·3	0·0	+3·0	15
16	327	4·5	2	22·4		S			11 14·3	−1·3	+1·3	265	11 20·5	−1·4	+1·0	281	11 22·9	−1·5	+0·5	301
31	2032	7·3	1	7·4		N			4 52·7	−1·4	−0·2	63	4 52·6	·	·	41		N		
31	2033	4·3	1	7·4	4 46·9	−0·8	−1·7	111	5 14·8	−1·1	−2·4	141	4 59·5	−1·1	−1·9	128	4 44·6	−1·0	−1·6	117
Aug. 9	3412	4·4	1	16·6	6 50·3	−1·0	+1·3	83	6 23·8	−1·2	+0·5	111	6 28·2	−1·0	+1·1	96	6 35·5	−0·8	+1·4	84
9	3412	4·4	2	16·6	7 57·3	−1·1	+1·3	234	7 16·5	−1·0	+2·7	207	7 30·4	−1·1	+2·0	222	7 40·7	−1·0	+1·6	235
9	3430	5·7	2	16·7		S			11 04·3	−2·3	−0·4	270	10 55·9	−2·6	−1·5	294		N		
13	401	6·3	2	20·6		N			8 49·7	−1·1	+0·4	294	8 47·6	·	·	321		N		
15	635	3·9	2	22·6	8 23·9	−0·4	+0·7	311		H				H				H		
15	659	6·4	2	22·7		S			11 14·9	−1·1	+1·5	260	11 22·1	−1·2	+1·1	278	11 25·4	−1·3	+0·5	299
15	661	4·6	2	22·7		S				N				N			11 36·3	−0·2	+3·2	208
15	669	4·0	1	22·8		S			11 52·0	−1·9	+0·2	111	11 55·3	−1·4	+1·2	91	12 03·6	−1·0	+1·8	72
15	671	3·6	1	22·8		S				N			12 02·9	−1·8	+0·1	116	12 05·2	−1·2	+1·2	94
15	692	1·1	1	22·9		N			17 19·4	−1·9	−0·4	78	17 17·8	−1·7	+0·5	55	17 24·1	·	·	25
15	692	1·1	2	22·9		N			18 41·1	−1·1	−1·3	272	18 28·5	−1·0	−2·3	294	18 04·8	·	·	323
Sept. 1	2718	6·7	1	9·8	3 09·8	−1·4	−0·2	118		G				S				S		
1	2733	6·4	1	9·9	5 55·0	−1·2	−1·2	101	6 11·6	−2·4	−2·7	136	5 57·0	−1·8	−1·4	116	5 45·9	−1·5	−0·9	101
1	2745	6·9	1	9·9		N			7 58·2	−0·5	+0·1	51		H				N		
3	3066	6·0	1	12·0		N			9 56·0	−0·3	+0·7	36		H				N		
5	3353	3·8	2	14·0	9 43·0	−0·8	−0·2	236	(9 21·9)	−0·5	+2·7	192	(9 31·9)	−1·0	+1·0	216	(9 33·3)	−1·1	+0·2	236
5	3360	6·3	1	14·0	9 52·2	−0·7	+0·1	44	9 46·6	−1·8	−0·5	84	9 43·6	−1·4	0·0	65	9 42·8	−0·9	+0·4	44
5	3360	6·3	2	14·0	10 51·9	−0·8	−1·4	271	10 55·0	−0·8	+0·6	225	10 54·5	−1·0	−0·3	246	10 47·1	−1·1	−1·1	268
10	462	5·9	2	18·9	7 03·2	0·0	+2·9	200		N				N			6 53·3	+0·2	+2·7	201
11	608	6·0	2	20·1	11 27·1	−1·6	+0·3	274	10 52·9	−1·5	+2·3	231	11 03·8	−1·6	+1·5	251	11 08·7	−1·5	+0·9	271
13	878	5·5	2	22·1	10 42·0	−1·2	+0·7	292	10 12·4	−0·7	+1·8	252	10 21·8	−0·9	+1·4	270	10 28·0	−0·9	+0·9	290
15	1141	5·6	2	24·2		S			12 46·6	−1·5	+1·2	267		S				S		
28	2685	7·0	1	7·2		N			5 13·2	−0·8	0·0	54		N				N		
28	2687	6·7	1	7·2		H			5 25·3	−1·3	−1·5	106	5 15·8	−1·1	−1·1	89	5 07·1	−0·9	−0·8	73
29	2846	6·9	1	8·2	3 16·3	−1·2	0·0	61	3 03·0	−2·2	0·0	87	3 02·1	−1·8	+0·3	74	3 01·6	−1·5	+0·5	62
Oct. 1	3142	6·8	1	10·2	4 09·7	−1·5	0·0	95	4 01·8	·	·	128	3 55·3	−2·1	−0·1	108	3 53·1	−1·6	+0·5	94
3	3412	4·4	1	12·2	1 50·9	−0·6	+1·7	75		S				S				S		
9	669	4·0	1	18·3	4 28·9	+0·5	+2·4	27		H				H				H		
9	669	4·0	2	18·3	5 06·2	−0·4	+0·8	307		H				H				H		
9	671	3·6	2	18·3	5 14·5	−0·2	+1·4	280		H				H				H		
9	675	5·7	2	18·3	5 39·5	+0·3	+3·0	202		N				N			5 32·1	+0·5	+2·8	202
9	677	4·8	2	18·3		N			5 40·3	−0·6	+0·1	304		G				N		
9	678	5·5	2	18·3	5 59·4	+0·1	+2·7	211		N				G			5 50·9	+0·3	+2·6	211
9	682	6·0	2	18·3	6 48·4	−0·4	+2·2	235	6 01·1	+0·7	+3·8	194	6 20·9	+0·1	+2·5	218	6 37·1	−0·1	+2·1	235
9	685	6·5	2	18·4		N			7 24·2	−1·2	+0·8	283	7 25·9	−1·5	0·0	305		N		
9	692	1·1	1	18·4		N			7 46·9	−0·4	+2·9	36	8 11·2	·	·	8		N		
9	692	1·1	2	18·4		N			8 48·9	−2·1	+0·1	290	8 41·7	·	·	321		N		
10	806	5·1	2	19·4	7 50·8	−0·7	+1·5	271	7 15·7	−0·2	+2·1	236	7 28·0	−0·4	+1·8	253	7 38·5	−0·5	+1·5	270
10	820	6·0	2	19·4	9 28·6	·	·	191		N				N				N		
11	944	5·7	2	20·4	7 31·9	−0·6	+1·0	295	7 08·2	0·0	+1·4	259	7 16·6	−0·2	+1·2	276	7 23·6	−0·3	+1·0	294
11	970	6·5	2	20·5	11 35·6	−1·4	+2·0	233		N				N			11 12·1	−1·1	+3·1	223
13	1198	6·2	2	22·5		N			9 21·2	−0·8	−0·2	309		G				N		

Date	Z.C. No.	Mag.	Ph.	Age of Moon	J EDMONTON, ALTA. W. 113°.075, N. 53°.533				K CALIFORNIA W. 120°.000, N. 36°.000				L OREGON W. 121°.000, N. 42°.500				M VANCOUVER, B.C. W. 123°.100, N. 49°.500			
					U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*
				d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Oct. 13	1210	5·9	2	22·5		N			11 09·0	−1·5	−0·2	301	11 01·8	−1·6	−1·9	330		N		
26	2791	5·4	1	5·5	0 41·3	·	·	156		N				N				S		
28	3100	6·4	1	7·7	3 35·6	−1·2	−0·4	76	3 32·9	−2·6	−1·0	107	3 26·7	−2·0	−0·3	90	3 22·5	−1·5	+0·1	75
29	3252	7·0	1	8·7	5 21·8	−1·2	−1·1	93		N			5 23·9	−2·3	−1·9	115	5 11·5	−1·6	−0·7	92
30	3379	6·4	1	9·7	3 33·4	−1·4	+0·5	75	3 13·0	−2·5	0·0	103	3 13·6	−1·9	+0·7	87	3 16·2	−1·4	+1·0	73
30	3383	6·5	1	9·7		N			4 23·2	−1·3	+2·0	32	4 37·2	−0·5	+2·8	10		N		
30	3405	7·0	1	9·8		H			9 16·1	−0·7	−1·9	106	9 06·4	−0·6	−1·0	81	9 00·1	−0·4	−0·5	57
31	3528	7·5	1	10·8	7 40·2	−0·2	+2·0	8	7 19·0	−1·5	+0·3	62	7 21·4	−1·1	+0·9	41	7 29·0	−0·4	+2·0	13
Nov. 5	635	3·9	1	15·9	10 03·4	−1·6	−2·8	130		N				N			9 59·1	·	·	149
5	635	3·9	2	15·9	10 53·6	−1·3	+1·8	210		N				N			10 26·8	·	·	188
8	1029	5·1	2	18·7	4 46·5	+0·5	+2·6	219		N				N				H		
8	1040	6·2	2	18·8		N			6 59·3	−1·0	+0·3	297	6 56·6	−1·3	−1·1	325		N		
10	1284	6·3	2	21·0		N			13 22·9	−2·1	−2·0	309	13 04·2	−1·5	−3·4	334		N		
12	1486	4·6	2	23·0		N			9 59·7	−0·7	+0·5	290	10 00·4	−0·7	−0·1	313	9 53·2	−0·7	−2·2	346
13	1589	6·0	2	24·0	10 39·5	−0·6	+1·0	290	9 59·8	·	·	218	10 19·5	−0·3	+2·0	253	10 30·3	−0·3	+1·3	278
13	1600	5·1	2	24·1		N			13 05·3	−1·6	−0·6	305	12 58·0	−1·1	−1·4	328	12 37·7	·	·	6
14	1712	3·8	1	25·1	13 11·8	−1·2	+1·3	88	13 01·6	−0·9	−1·5	151	12 55·9	−0·9	−0·1	127	12 56·9	−0·9	+0·9	106
14	1712	3·8	2	25·1		S			14 05·2	−2·2	+1·5	259	14 09·5	−1·6	+0·5	281	14 08·8	−1·1	+0·1	300
16	1937	6·1	2	27·1	13 18·9	−0·3	−0·1	325	13 04·4	−0·6	+1·5	262	13 11·4	−0·5	+0·9	284		H		
16	1941	4·8	2	27·1		N			13 28·7	0·0	−2·1	345		N				N		
25	3196	6·1	1	6·1	0 59·6	−2·0	−1·0	127		N				G				S		
26	3353	3·8	1	7·2	6 01·5	−0·2	+0·2	31	6 02·0	−1·1	−0·8	81	5 57·8	−0·8	−0·2	59	5 56·8	−0·5	+0·3	36
26	3360	6·3	1	7·3		N			7 15·5	−0·3	+0·2	48		H				N		
27	3496	7·2	1	8·2		N			6 05·2	−0·9	+1·1	37	6 15·5	−0·2	+2·7	8		N		
27	3505	5·6	1	8·3		N			8 10·1	−0·2	+1·2	28		N				N		
28	55	6·4	1	9·1	0 26·2	−0·5	+2·4	19		S				S				S		
29	202	7·0	1	10·2	4 01·8	−1·0	+1·6	37	3 25·4	−1·9	+1·3	69	3 33·9	−1·4	+1·7	53	3 44·6	−1·0	+2·1	35
29	212	7·3	1	10·3	7 30·1	−0·5	+2·2	11	7 10·6	−1·7	−0·1	71	7 10·7	−1·3	+0·6	49	7 16·1	−0·8	+1·7	22
30	322	5·7	1	11·2	3 27·6	·	·	6	2 34·3	−0·9	+2·3	44	2 50·3	−0·6	+2·8	26	3 12·8	·	·	1
30	327	4·5	1	11·2		N			3 55·0	−0·9	+3·1	25	4 19·9	·	·	356		N		
Dec. 6	1141	5·6	2	17·5	13 55·1	−1·4	+0·4	221		N				N				N		
7	1238	6·1	2	18·4		N			8 09·0	−1·7	−0·3	301	8 00·5	−1·7	−2·2	331		N		
9	1441	6·4	2	20·3	7 14·2	−0·6	−1·1	338	7 06·7	−0·3	+1·0	277	7 11·1	−0·4	+0·5	299	7 11·3	−0·4	−0·3	325
9	1442	Var	2	20·3	7 35·0	−0·6	+0·7	300	7 08·0	−0·1	+2·2	245	7 19·3	−0·3	+1·4	269	7 27·0	−0·3	+0·9	291
11	1658	6·4	2	22·4	9 59·8	−1·0	+3·2	239		N				N				N		
12	1772	4·0	1	23·6	12 52·8	−1·1	−0·2	126		N			12 58·9	−0·4	−3·2	173	12 45·1	−0·8	−0·9	147
12	1772	4·0	2	23·6	14 08·2	−1·4	−0·2	285		N			13 44·8	−2·9	+2·5	241	13 50·6	−1·8	+0·9	264
21	2997	7·1	1	2·6		H			1 51·4	−1·0	−0·7	80	1 47·2	−0·8	−0·3	61	1 44·7	−0·5	0·0	41
22	3149	7·1	1	3·6	0 00·0	−1·3	−0·4	86		S				S				S		
23	3313	6·8	1	4·7		H				N				G			3 49·7	−1·2	−1·8	105
24	3461	6·4	1	5·7		N			5 32·8	·	·	353		N				N		
27	298	7·2	1	8·7		N			4 48·8	−1·8	+1·2	51	4 58·0	−1·2	+2·2	27		N		
27	303	6·6	1	8·8	6 32·2	−0·9	−1·3	87		N			6 46·4	−1·7	−4·0	128	6 26·7	−1·3	−1·5	96
27	308	6·7	1	8·8		N			7 44·2	−0·9	+0·1	57	7 46·4	−0·8	+1·0	32		N		
29	526	6·9	1	10·7	3 15·3	−1·1	+1·6	59	2 41·8	−1·9	+0·8	95	2 47·6	−1·4	+1·5	77	2 57·1	−1·0	+1·9	59
30	659	6·4	1	11·6	0 57·4	−0·2	+2·2	52		S				S				S		
30	667	5·3	1	11·7		N			2 14·5	−0·2	+3·1	30		G				N		
30	669	4·0	1	11·7	2 30·8	−1·0	+1·3	90	2 10·7	−2·2	−1·2	133	2 09·5	−1·2	+0·8	108	2 15·7	−0·8	+1·5	90
30	671	3·6	1	11·7	2 37·3	−1·4	+0·6	114		N			2 26·5	·	·	144	2 21·8	−1·1	+0·8	114
30	677	4·8	1	11·7	3 47·9	−1·2	+1·5	66	3 18·0	−2·0	+0·3	107	3 21·5	−1·5	+1·2	87	3 29·8	−1·0	+1·8	68
30	685	6·5	1	11·8	5 46·8	−1·5	+0·4	76	5 46·4	·	·	137	5 31·7	−2·3	−0·5	106	5 28·6	−1·7	+0·7	82
30	692	1·1	1	11·9	7 22·3	−1·3	+0·4	54	7 19·3	−2·4	−2·0	114	7 09·4	−2·0	−0·5	89	7 05·5	−1·7	+0·5	66
30	692	1·1	2	11·9	8 29·9	−1·0	−2·1	290	8 34·5	−1·9	+1·0	230	8 34·2	−1·6	−0·4	253	8 25·0	−1·4	−1·3	276
31	814	5·3	1	12·9	7 47·5	−1·5	+1·8	37	7 27·4	−2·4	−0·9	100	7 23·4	−2·1	+0·3	78	7 25·2	−1·7	+1·4	53

How To Use the Prediction Tables

Universal time is Greenwich time, counted from 0 to 24 hours, beginning at midnight; times greater than 12:00 are p.m. To convert to standard times in the United States and Canada, subtract the following number of hours: for AST, 4; EST, 5; CST, 6; MST, 7; and for PST, 8. If necessary, add 24 hours to the UT before subtracting, and use the previous calendar date.

For example, consider the first line of the table, for the star Z.C. 3470, on January 4, 1960. It is of magnitude 7.0, the phenomenon is a disappearance (at the moon's dark eastern edge), the moon's age being 5.2 days. The table on the first page of the supplement also identifies this star as 34 G. Piscium.

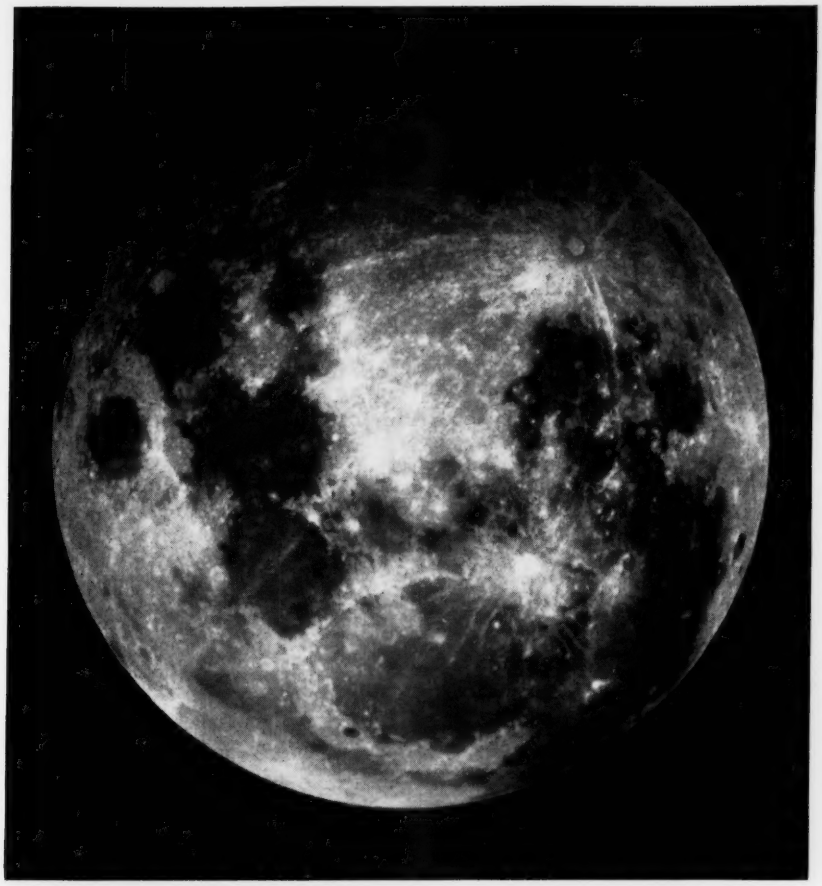
The next column states that at standard station **A** (LoS, +72°.5; LS, +42°.5, in central Massachusetts) the disappearance will occur at 1:47.2 UT. The corresponding Eastern standard time (EST) is 8:47.2 p.m. on January 3rd.

Suppose an observer is in Albany, New York, at Lo +73°.8, L +42°.7. The **a** quantity for **A** is −0.9 and **b** is −2.4. The correction to the standard station time is, therefore,

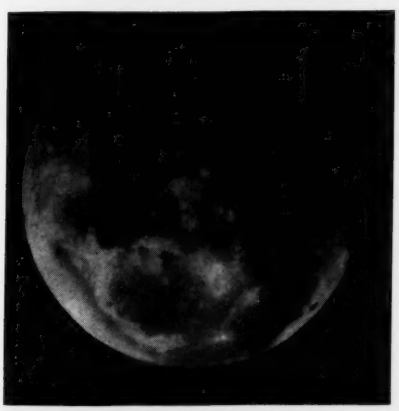
$$-0.9(73°.8 - 72°.5) - 2.4(42°.7 - 42°.5) = -1.65 \text{ minutes.}$$

Hence, the disappearance at Albany is due at 8:47.2 − 1.6, or at 8:45.6 p.m. EST on January 3rd.

The table also tells that the point of disappearance of the star at the moon's edge will be 112° from the north point, counted eastward around the limb. This same angle will hold approximately for Albany.



The eclipse taken with a 16½-inch reflector (above) and a 4-inch (below).



SEPTEMBER'S PENUMBRAL ECLIPSE OF THE MOON

ON the evening of September 16th, the moon was totally immersed in the penumbra of the earth's shadow for 27 minutes, mid-eclipse occurring at 1:02.8 Universal time on the 17th (see page 650, September issue). Three amateurs reported their successful photography of the event, pictures from two being reproduced here.

The view at the top of this page was taken by Gert Schmitz of the Rocket City Astronomical Association, Huntsville, Alabama, using the society's 16½-inch reflector. The 1/15-second exposure, on Panatomic-X film, was made at 0:50 UT, just after the moon had become totally immersed in the penumbra.

John A. Marshall, Elmhurst, Illinois, noticed at 1:00 UT that the moon was duller than usual. With a 4-inch reflector he took the pictures at the left, the top one at 1:20 (3½ minutes after the moon started to leave the penumbra), the other at 1:30. Exposures were 1/100 and 1/50 second, respectively, on Polaroid 47 film.

At Niagara Falls, New York, George M. Bramann took 21 color pictures of the event at seven-minute intervals. Microphotometer readings showed clearly the brightening of the moon as it emerged from the penumbral shadow.

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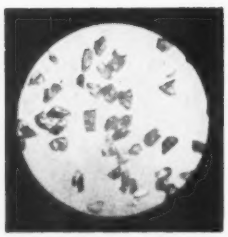

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DEEP-SKY WONDERS

WHEREVER there is an especially imposing nebula in the sky, the smaller objects around it tend to be neglected by amateurs. In the general region of Andromeda we have the magnificent galaxy M31 and the somewhat elusive but marvelous M33. Therefore, few observers bother with M74 in Pisces.

A broadside spiral, M74 (NGC 628) is located at right ascension $1^h\ 34^m.0$, declination $+15°\ 32'$ (1950 co-ordinates). Its diameter has been measured on photographs as 8′, and the visual magnitude is 10 or 11. This galaxy is visible in a 2-inch finder as a gray patch, and a 4-inch telescope reveals it as slightly larger than M13, the great globular cluster in Hercules, but decidedly fainter. A 10-inch shows that the central portion is brightest. No spiral arms can be seen, but it is obviously not a "nebulous star," as some older accounts suggest.

M74 is easy to find, 5.2 minutes east and 27′ north of Eta Piscium (see the chart on page 630 in September, 1959). If the observer sets Eta on the southern edge of a low-power field and lets the stars drift across, M74 will enter the field in a few minutes. This technique has a good deal to recommend it, for the eye becomes much more sensitive by staring at a relatively blank sky for a while. Also, try viewing this galaxy with averted vision, which should give a further gain of up to a stellar magnitude.

Indeed, in most observing locations eye sensitivity is decreased by stray light, overall sky light, and reflections from the telescope tube. By shielding his head and the eyepiece with a black cloth, as a portrait photographer does, the observer will surely increase his ability to see faint objects, such as M74.

WALTER SCOTT HOUSTON
Rte. 3, Manhattan, Kans.

SUNSPOT NUMBERS

The following American sunspot numbers for September have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

September 1, 287; **2,** 236; **3,** 193; **4,** 160; **5,** 151; **6,** 162; **7,** 161; **8,** 140; **9,** 132; **10,** 141; **11,** 136; **12,** 153; **13,** 162; **14,** 158; **15,** 146; **16,** 111; **17,** 81; **18,** 105; **19,** 123; **20,** 127; **21,** 126; **22,** 129; **23,** 96; **24,** 114; **25,** 101; **26,** 96; **27,** 86; **28,** 91; **29,** 99; **30,** 90. Mean for September, 136.4.

Below are provisional mean relative sunspot numbers for October by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations in Locarno and Arosa.

October 1, 54; **2,** 72; **3,** 81; **4,** 97; **5,** 115; **6,** 128; **7,** 130; **8,** 115; **9,** 103; **10,** 91; **11,** 78; **12,** 81; **13,** 70; **14,** 102; **15,** 96; **16,** 116; **17,** 107; **18,** 116; **19,** 84; **20,** 99; **21,** 111; **22,** 129; **23,** 135; **24,** 143; **25,** 137; **26,** 126; **27,** 112; **28,** 110; **29,** 115; **30,** 117; **31,** 130. Mean for October, 106.5.

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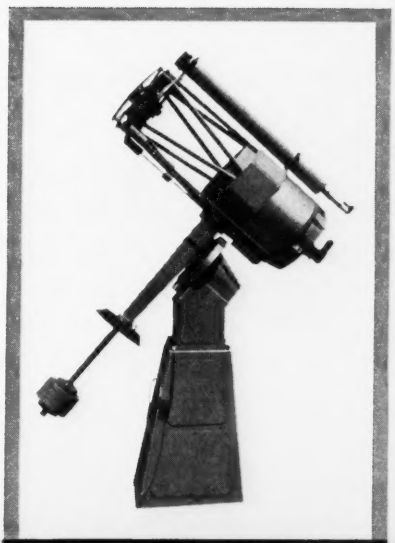

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The "Red Tunnel" at a Sunrise Total Solar Eclipse

At the October 2nd total eclipse of the sun, my wife and son (John W. Stewart) observed with me from a hilltop five miles northwest of Nashua, New Hampshire, and only two or three miles inside the northern limit of totality. We had gone there to escape the stormy weather that continued at places farther south and east, and were rewarded by observing a striking optical phenomenon associated with the passage of the moon's shadow through the earth's atmosphere.

To our east, the eclipsed sun was thoroughly obscured by a great bank of storm clouds, which extended overhead and for many miles west and south. But along the horizon, in the north, west-northwest, and west-southwest, there were three narrow, long slits of distant clear sky.

As totality approached, the northern rift turned to a light lemon yellow, while the westerly slits showed saffron (yellow-tan), exactly the color I had seen all around the sky horizon under the huge deep blue lunar shadow at the long eclipse over the Pacific Ocean in 1937.

During totality on October 2nd, the lemon color to the north remained unchanged, as it was fed by sunlight outside the umbral shadow. The saffron in the slit to the west-northwest became a dirty tan, but the west-southwestern opening provided the most dramatic appearance. It was a shining deep red, something like a ruby, although perhaps of a less pure color. There was something almost shocking about that luminous red in the predominantly dull gray landscape, a color scarcely matched at any sunset but possibly seen in an aurora borealis.

After perhaps 25 quick seconds of totality, the whole landscape brightened with remarkable suddenness. The ruby red patch must have gone as instantaneously, although none of us looked just in that direction until seconds later.

This transitory red glow does not seem to have attracted general attention in the past. It is probable that an observer sees it only if he is inside the umbra and looking very nearly along the axis of the moon's shadow, through hundreds of miles of air. These conditions require that the sun be very low in the sky. There is no primary light source inside the nearly cylindrical umbral "tunnel." Sunlight is first scattered or diffused by air outside the shadow cylinder into it, and then scattered axially by air molecules inside the umbra. The glow should be red, because air transmits red light far better than shorter wave lengths.

Although probably of slight astronomical importance, the ruby patch is a magnificent wonder of nature. It is far harder to observe than the sun's corona, because the viewer must be very close to the sunrise or sunset terminus of an eclipse track. Does a similar glow appear in the other direction along the umbra, toward the moon and sun? Should the moon's dark side seem red, to match the opposite horizon's red?

The next total eclipse visible in the United States crosses Maine on the afternoon of July 20, 1963, its sunrise point being in Hokkaido, Japan. Observers there, forewarned and perhaps favored by less cloud, can repeat our observations of the ruby glow and check its explanation in detail.

JOHN Q. STEWART
Princeton University Observatory
Princeton, N. J.

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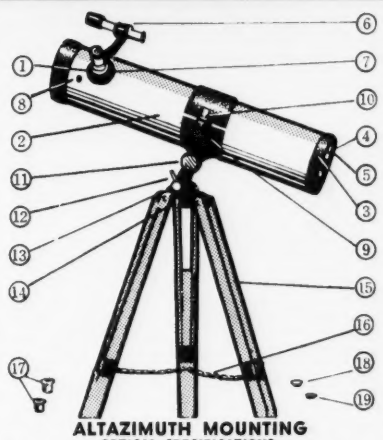

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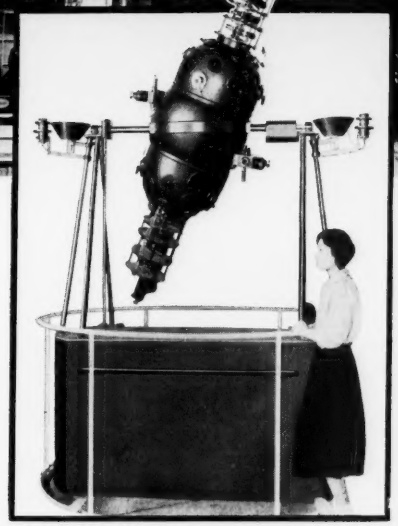

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BOOKS AND THE SKY

ASTRONOMY

Theodore G. Mehlin. John Wiley and Sons, Inc., New York, 1959. 392 pages. $7.95.

TWO SIGNIFICANT innovations are provided in this textbook by the astronomer of Williams College. The first and most obvious is the strikingly different order of presentation.

After a brief introduction on "The Tools of the Trade," Dr. Mehlin plunges directly into "The Life Story of a Star," and continues with stellar distances and motions, the sun, binary stars, intrinsic variables, and galaxies. This portion would constitute the first-semester subjects when used for a year course. The second semester would open with the chapter on the Milky Way galaxy, and terminate with the solar system.

Without question, the evolution of stars makes an impressive beginning, but, for a captive audience taking an introductory course in astronomy, a spectacular ending may be even more important. For some teachers, however, the discussion of the solar system's origin, which concludes this book, will be an appropriate finale.

The novel arrangement does not seem to work any hardships on logical presentation. There is no particular reason, for example, why gravitation and the two-body problem should not be introduced in connection with binary stars rather than with planets. This reviewer feels, however, that Mehlin's order of subjects requires somewhat more background in science than does, say, a historical approach.

The second innovation is the general lack of specific details. This is especially evident in the chapter on variable stars, where very few are mentioned by name. Except for a single allusion to Delta Cephei, no classical Cepheids and novae are identified, nor is any coverage given to peculiar stars or those with extended atmospheres. There is no table of data for 1st-magnitude stars. This book does not reveal the name of the most massive or luminous star or state how massive or luminous such a star might be.

This drawing, held at a distance of 21 inches, illustrates the appearance of the earth-moon system as seen from Venus with a 100-power telescope when that planet is nearest the earth. From Theodore G. Mehlin's "Astronomy," courtesy John Wiley and Sons, Inc.

On the other hand, the methods for obtaining the masses of stars are spelled out in considerable detail with equations and numerical examples. While this approach limits the value of the book as a reference, it may help the beginning student to concentrate on important physical methods rather than on memorizing details.

Although the book keeps to simple mathematics (logarithms but no trigonometry), it contains longer discussions of a semimathematical nature than are generally found in textbooks of this level. There are, for instance, a considerable section on star counts, a commendable account of dynamical parallaxes, and a good treatment of the Foucault pendulum.

The stimulus of a new presentation of astronomical fundamentals is sufficient justification for another textbook in this already crowded field. Moreover, the

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usable lifetime of a college astronomy text is scarcely more than five years, due to the rapid progress of modern astronomy. Mehlin's book contains numerous points that would not have been included several years ago, such as the distinction between the physical nature of meteors and meteorites, and the discussion of artificial satellites.

Several recent developments have escaped this text, however. The older Wildt model of Jupiter's interior is given instead of the newer belief that the Jovian sphere is essentially solid hydrogen. In the table of statistics of the solar system (Appendix V), old values are given for the mass of Mercury and for the diameter of Neptune. The Crab nebula is discussed, but no explicit mention is made of its radio emission. For that matter, radio astronomy as a whole is practically ignored except for a brief discussion of radio telescopes and resolving power. Radio sources and colliding galaxies are not mentioned, and 21-centimeter work is casually covered in one brief paragraph.

Several errors, mostly historical, were noted in the text. Messier's catalogue was not entitled *Odd Objects* (page 167). Copernicus used epicycles rather than eccentric orbits to account for nonuniform motion of the planets (page 232). The book to the contrary, Piazzi's discovery of Ceres was accidental (page 254), and, finally, Uranus was called "Herschel" only in France (page 267).

In spite of its shortcomings, Mehlin's *Astronomy* is welcome for its fresh approach and for numerous illustrations not used in other astronomical textbooks. The line drawings are excellent, but some of the halftones suffer from excessive contrast. The jacket design, incidentally, features a handsome color rendition of the rising moon and unfolds to reveal a wall-type star map.

OWEN GINGERICH
Harvard Observatory

THE INDIVIDUAL AND THE UNIVERSE

A. C. B. Lovell. Harper and Brothers, New York, 1959. 111 pages. $3.00.

ASTRONOMICAL RESEARCH is not what it used to be, either in its methods or in its sources of support. In this book, based on radio talks given in England, A. C. B. Lovell expresses vividly the uneasy position of the modern astronomer, deeply excited by the unparalleled opportunities for discovery that are unfolding, yet anxious and troubled by the implications of his increasing dependence upon the state for financial support and ideological respectability.

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conception and use, is animated by an enthusiasm comparable to that of Galileo with his first refractor. And well he may be, for, to cite just one example, in little more than a decade this new instrument has penetrated intergalactic space far beyond the range of optical telescopes.

Professor Lovell considers the prospect of optical observations from space satellites similar in importance to the radio telescope. He feels that these two lines of advance will so complement each other as to clarify some of the deepest questions in cosmology. He especially hopes for a decision between the evolving universe of Lemaitre and Gamow and the hypothesis of continuous creation advocated by Gold and Hoyle.

Either school admits the expansion of the galactic universe indicated by the red shifts in the spectra of galaxies. But continuous creation of matter implies a universe in equilibrium, independently of time. Any large region of space should contain as many galaxies as any other, allowing for random fluctuations. If, however, all of the material in the observable universe was present in the exploding "primeval atom," then the concentration of galaxies must be steadily decreasing with time because of the universal expansion. Thus the farthest reaches of space, being observed as they appeared in the distant past, should reveal greater concentrations of galaxies than the regions nearer to us. Lovell is confident that radio telescopes and optical telescopes in space will soon extend the range of observation enough to permit such a crucial test of the outstanding cosmological theories.

Here the author expresses a really awesome thought. Noting that telescopes already can detect galaxies so distant that they are receding at more than a fifth the speed of light, he predicts that we shall soon reach the ultimate limit of observable time and space. The radiation from galaxies receding at nearly the speed of light will be so degraded in frequency and quantum energy that we shall be unable to detect it. "The present observable horizon of the universe will be pushed back by a limited amount in the near future, perhaps to a few thousand million light-years. Then we must be content. No further strivings or inventions of man will enable us to probe the conditions which existed in epochs of history beyond these few thousand million years."

But is this so? Science has outstripped its own prescribed limitations again and again. Yet it is manifestly unsafe to extrapolate very far from so brief a span of experience. In Whitehead's disturbing phrase, science is provincial in time. Like the wave of pioneers that disperses exuberantly into a continent, only to face at last the implacable sea, perhaps the scientific adventurer also must reach a truly ultimate boundary that nothing

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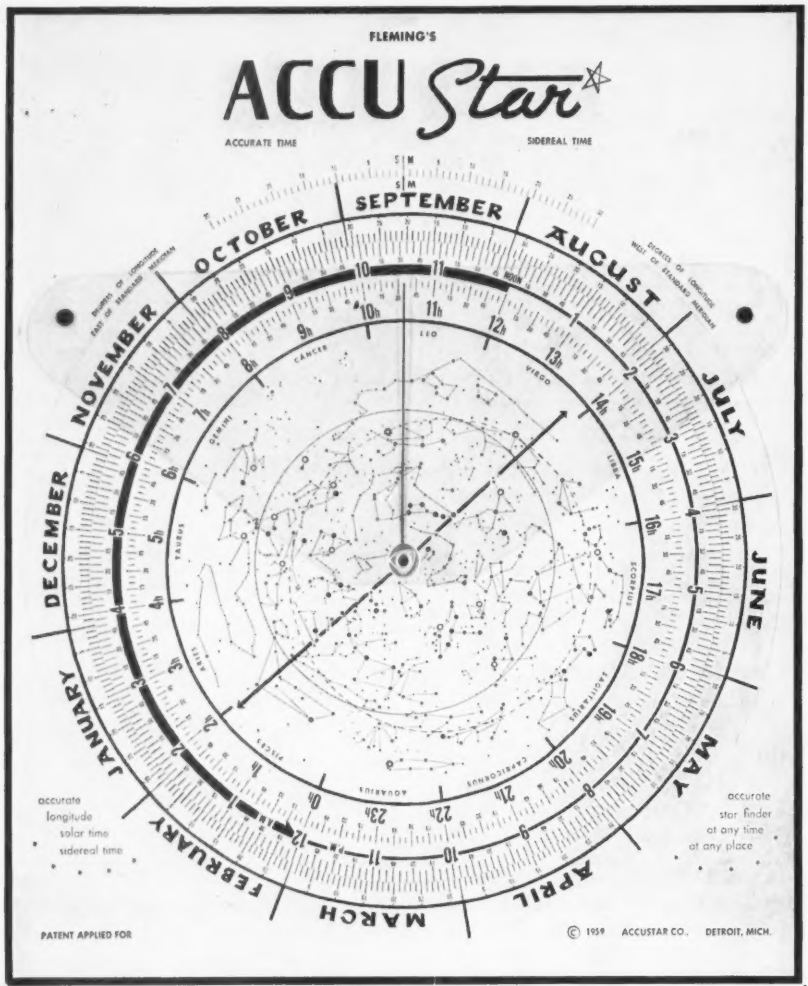

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can penetrate. Personally, I cannot think so; yet I must acknowledge that any justification for this attitude lies not so much in scientific reasoning as in what Lovell quite properly would term metaphysics.

"The devices of a world war have been forged, with the help of the fear of another, into a system of scientific experiments which take us back through time and space to deal with the problems of the origin of the universe." This ironic view of the astronomer's situation in our time is the theme of much of the author's thinking. He remarks that, after the struggle against secular authority reached its climax in Galileo's career, the state generally let science alone. With few exceptions, observatories and other scientific facilities have been provided and maintained by private gifts or by royal patronage that was more personal than political.

Since World War II, that situation has been abruptly reversed. Astronomical research has become vitally important to the military services of the great powers, in connection with conditions in the high atmosphere, solar influences on the earth, and space rocketry. At the same time, advances in methods and instrumentation have developed needs for unprecedented sums of money for such research, just when large private fortunes are becoming a social curiosity.

Professor Lovell is particularly impressed with the recent development of astronomy in the U. S. S. R., where state support has been most notable. He is unreserved in his praise of the Russian scientists and their achievements — unduly so, one may feel at times, as when he cites the pioneering work of Otto Schmidt and his associates in developing the dust-cloud hypothesis of the origin of the solar system, but omits mention of Whipple or von Weizsäcker. He expresses deep concern over the decline of British leadership in optical astronomy and the imminent eclipse of its early superiority in radio telescopes. He foresees a similar eclipse of the United States if it does not make a better-organized, more serious effort to recover leadership in rocketry and in astronomical research. ". . . I find few things more symbolic than the ease with which the U. S. S. R. launched Sputnik One, weeks ahead of schedule."

Apart from the involvement of science in international rivalry, the author is much concerned with the ambiguous position in which scientists are placed by their dependence upon military and other state support, and — in Russia — by the ideological strictures within which they must work. He notes, for example, that the astronomical instrumentation carried in a rocket or satellite represents only a small fraction of the cost of the shot, and often is of only incidental interest to the military sponsors of the rocket development. Such support, he feels, is a precarious basis for free research; it leaves the scientist highly vulnerable to pressures

to compromise his scientific objectives in favor of "hardware." In this connection, the author emphasizes the essential principle that fundamental research cannot be planned in terms of specific objectives, and that the unanticipated discoveries that result from such efforts frequently are more important than the intended goals.

This is an excellent little book, reflecting a warm and unpretentious personality. Through its pages, Professor Lovell shares with us in his quiet way something of the disciplined excitement and concern of a man of the 20th century who chose also to be a scientist.

J. H. RUSH
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ISAAC NEWTON, *Beulah Tannenbaum* and *Myra Stillman*, 1959, *McGraw-Hill*. 128 pages. $3.00.

Written for young readers, this short biography of Sir Isaac Newton tells many anecdotes that portray his life, and describes some of the monumental contributions he made to astronomy and other sciences.

THE SKY OBSERVER'S GUIDE, *Newton Mayall, Margaret Mayall,* and *Jerome Wyckoff*, 1959, *Golden Press*. 125 pages. $2.95.

Amateur observers can find here basic information on how to use telescopes, binoculars, and the unaided eye to observe the moon, sun, stars, and other celestial objects. There are color star maps and illustrations.

OUR SUN, *Donald H. Menzel*, 1959, *Harvard University Press*. 350 pages. $7.50.

This is an extensively revised and expanded edition of a popular work originally published in 1949 and reviewed in SKY AND TELESCOPE for October of that year. It reflects a decade of fruitful solar research with greatly advanced observational techniques.

THE UNITY OF THE UNIVERSE, *D. W. Sciama*, 1959, *Doubleday*. 228 pages. $3.95.

Here is a book on cosmology whose readers do not require a formal background in physics and astronomy. The author traces the history of man's view of the cosmos up to the modern steady-state theory.

EXPLORING EARTH AND SPACE, *Margaret O. Hyde*, 1959, *McGraw-Hill*. 160 pages. $3.00.

This is the latest edition of a book for younger teen-agers, telling about the earth, its atmosphere, and artificial satellites. The emphasis throughout is on very recent work.

APPARENT PLACES OF FUNDAMENTAL STARS 1960, 1959, *Astronomisches Rechen-Institut*, Grabengasse 14, Heidelberg, West Germany. 510 pages.

The 20th of a series, this annual volume lists apparent positions of bright stars, giving right ascensions to 0.001 second and declinations to 0".01, at 10-day intervals, for 1,535 stars. Prepared under the auspices of the International Astronomical Union, the series was previously published in England, but content and presentation remain unchanged.

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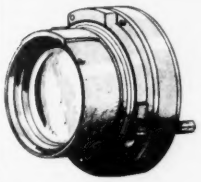

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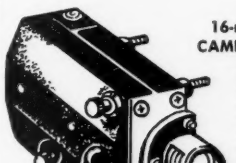

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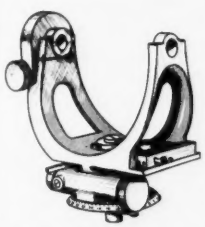

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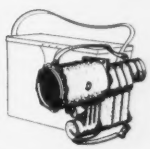

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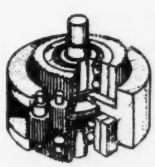

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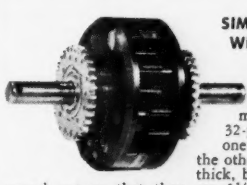
The 1:1 reverse ratio spur gears are 48-tooth, 32-pitch brass with 3/16" available face. On one side the shaft is 23/64" diam. for 11/16" and has a pinhole, then increases in diam. to 0.377" for the remaining 3/16" of length. On the other side, the shaft is 0.377" diam. ¼" long. 2-13/16" diam. is required to clear the body. Stock No. A6-115. Price **$15.00** each.



SIMPLE DIFFERENTIAL WITH SPACED-OUT SUN GEARS

1:1 reverse ratio spur gears are aluminum, 3/32" face, 32-pitch, 32-tooth on one side, 48-tooth on the other. The body is ¾" thick, but the sun gears are spaced out so that they are 1½" apart. ¼"-diam. shaft on each side is 23/32" long. Over-all length, 3⅛". Requires 1-23/32" diam. to clear the body. Stock No. A6-124. Price **$4.50** each.

VARIABLE-SPEED BALL DISK INTEGRATORS (All shafts ball-bearing supported)

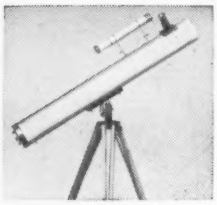
No. 145. Forward and reverse 2¼-0-2¼. Input shaft spline gear 12 teeth 9/32" diam., ⅜" long. Output shaft 15/64" diam. x 15/32" long. Control shaft 11/32" x ⅜" long. Cast-aluminum construction. Approx. size 3" x 3" x 2¾". Price $17.50

No. 146. Forward and reverse 4-0-4. Input shaft 5/16" diam. x ¾" long. Output shaft 15/64" diam. x 9/16" long. Control shaft 11/64" diam. x 11/16" long. Cast-aluminum construction. Approx. size 4½" x 4½" x 4". Price $18.50 each.

Send full amount with order. All prices net f.o.b. Pasadena, Calif. No C.O.D.'s, please.

C&H SALES CO. 2176 East Colorado St. • Pasadena 8, Calif. MUrray 1-7393

ITEMS ON THIS PAGE ARE ESPECIALLY SUITABLE FOR CHRISTMAS GIFTS!



3-inch Astronomical Reflector

60 to 180 Power
An Unusual Buy!

Assembled — ready to use! See Saturn's rings, the planet Mars, huge craters on the moon, star clusters, moons of Jupiter, double stars, nebulae, and galaxies! Equatorial-type mounting with locks on both axes. Aluminized and over-coated 3"-diameter f/10 primary mirror, ventilated cell. Telescope comes equipped with a 60x eyepiece and a mounted Barlow lens, giving you 60 to 180 power. A finder telescope, always so essential, included. Sturdy, hardwood, portable tripod.

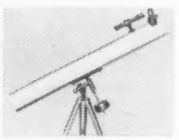
FREE with Scope: Valuable **STAR CHART** plus 272-page **"HANDBOOK OF THE HEAVENS"** plus the book **"HOW TO USE YOUR TELESCOPE."**

Stock #85,050-Y.....$29.95 ppd.

See the Stars, Moon, Planets Closeup!

4¼" ASTRONOMICAL TELESCOPE

REFLECTOR TYPE — Up to 255 Power!



With this scope you can see the craters on the moon, the rings of Saturn, double stars. Mirror guaranteed to give theoretical limit of resolution. Rack-and-pinion focusing, removable mirror mount, counterweight. Real equatorial mounting — only one adjustment follows stars! Aluminum tube. 6-power finder telescope. 2 standard-size eyepieces and mounted Barlow lens give you powers of 40x, 90x, 120x, 255x. Mirror f/11, and corrected to better than ¼ wave length. FREE with Scope: — Valuable **STAR CHART** plus 272-page **"HANDBOOK OF THE HEAVENS"** plus **"HOW TO USE YOUR TELESCOPE"** book.

Stock #85,006-Y.....$74.50 f.o.b. Barrington, N. J.

WAR-SURPLUS TELESCOPE EYEPIECE

Mounted Kellner Eyepiece, Type 3. Two achromats, focal length 28 mm., eye relief 22 mm. An extension added, O.D. 1¼", standard for most types of telescopes. Gov't. cost $26.50.

Stock #5223-Y.....$7.95 ppd.

50-, 150-, 300-POWER MICROSCOPE

Amazing value — equal of a $75.00 instrument! 3 achromatic objective lenses on revolving turret! Imported. The color-corrected, cemented achromatic lenses in the objectives give you far superior results to the single lenses found in other microscopes selling in this range. Results are worth the difference! Fine rack-and-pinion focusing.

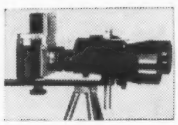
Stock #70,008-Y.....$14.95 ppd.

MOUNTED 500-POWER OBJECTIVE

. . . Threaded for easy attachment on microscope above. Achromatic lenses for fine viewing. 3-mm. focal length.

Stock #30,197-Y.....$5.00 ppd.

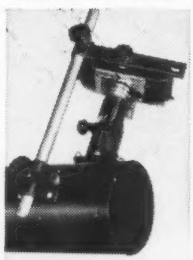
NEW BINOCULAR-TO-CAMERA HOLDER
For Exciting Telephoto Shots
Will fit any camera.



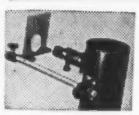
Bring distant objects 7 times nearer with a 35-mm. camera, 7 x 50 binocular, and our NEW BINOCULAR-TO-CAMERA HOLDER. Ideal for photographing the constellations, star clusters, the moon, as well as cloud formations, wild life, vistas. Camera and binocular attach easily. Use any binocular or monocular — any camera, still or movie. Take color or black-and-white. Attractive gray crinkle and bright chrome finish, 10" long. Full directions for making telephotos included.

Stock #70,223-Y.....$11.50 ppd.

Take Pictures Through Your Telescope with the EDMUND CAMERA HOLDER for TELESCOPES



Bracket attaches permanently to your reflecting or refracting telescope. Removable rod with adjustable bracket holds your camera over scope's eyepiece and you're ready to take exciting pictures of the moon. You can also take terrestrial telephoto shots of distant objects. Opens up new fields of picture taking!



SUN PROJECTION SCREEN INCLUDED

White metal screen is easily attached to holder and placed behind eyepiece. Point scope at sun, move screen to focus . . . and you can see sunspots!

All for the low, low price of $9.95

Includes brackets, 28¾" rod, projection screen, screws, and directions. Aluminum . . . brackets black crinkle painted.

Stock #70,162-Y.....$9.95 ppd.

NOTICE!

EDMUND IS NOW HEADQUARTERS FOR MATH LEARNING AND TEACHING AIDS!

Play This New Game — MATH MAGIC . . . The Fun-Way to Math Skill!

Educator-approved! 3 fascinating games in one! Great fun for the whole family. Increases skill at addition, subtraction, multiplication, division. Includes dial and spinner, numbered cards, plastic tokens, etc. — also rules and directions.

Stock #70,204-Y.....$3.00 ppd.

D-STIX Construction Kits

Shape Your Ideas Fast!

Scientists, executives, planners, designers — all find D-STIX simplify visualization and demonstration of complex ideas. D-STIX — colored wood sticks ⅛" thick and "easy-on" rubber joints approx. 3/16" diam. — help you work out molecular structures, geometric figures, structural members, shapes, models of scientific apparatus. Used by professional men, educators, hobbyists. Big basic kit contains 230 or 370 pieces. Additional parts in supplementary kit. Far superior to other kits of wood or metal. Money-back guarantee.

Stock #70,209-Y....(230 pcs.).....$3.00 ppd.
Stock #70,210-Y....(370 pcs.).....$5.00 ppd.
Stock #70,211-Y....(452 pcs.).....$7.00 ppd.

Ideal for Beginners . . . STARMASTER ASTRONOMY SET!

Bring the thrills and wonders of outer space right into your home with this fascinating, educational Astronomy Set. De Luxe, 37-piece Set includes separate film projector and action pictures of a trip to the moon, from blast-off to return. Exciting views of the moon, planets, comets, distant galaxies, sun explosions, star clusters, other space wonders.

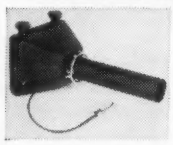
Also star projector and constellation projector (each approx. 4½" high). Projectors show many great constellations and stars, outline forms of Big Bear, Sagittarius, Southern Cross and others, for easy identification.

Also includes 10x telescope (single-element lens, meniscus, nonachromatic) with 1" aperture, suitable for viewing the moon.

Power source, flashlight pointer, and instructions included. Lower-priced Junior Set with single projector also available, but without telescope.

Stock #70,234-Y....De Luxe.....$10.00 ppd.
Stock #70,233-Y....Junior.....$ 5.00 ppd.

TELESCOPE ROLL-FILM CAMERA



This model uses rolls of #127 film. Picture area will be a circle 1-9/16" in diameter.

The advantage of this model is the ease of using roll film. With each camera you get a piece of ground glass. Before loading film in the camera, you focus the telescope. Then lock it in this position. For positions other than infinity, you can scribe a mark on your tube.

Stock #70,182-Y.....$29.50 ppd.

SHEET-FILM CAMERA

Uses sheet film 2¼" x 3¼" size. Camera box size is 3" x 4" x 5".

Stock #70,166-Y.....$39.50 ppd.

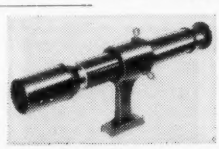
ASTRO COMPASS and STAR FINDER

Gov't. Cost $75 — Price $14.95 ppd.

Determines positions of stars quickly. Shows various celestial co-ordinates. An extremely useful star finder which can be rotated through 60° angles along calibrated degree scale. Has single eye lens with viewing stop, two spirit levels for aligning, tangent screw with scale for fine precision readings, azimuth scale graduated in two-degree intervals, adjustable tilting azimuth scale for angle reference of stars on distant objects. War surplus. Gov't. cost $75.00. Instructions, carrying case included.

Stock #70,200-Y.....Only $14.95 ppd.

6X FINDER TELESCOPE



Has crosshairs for exact locating. You focus by sliding objective mount in and out. Base fits any diameter tube — an important advantage. Has 3 centering screws for aligning with main telescope. 20-mm.-diameter objective. Weighs less than ½ pound.

Stock #50,121-Y.....$8.00 ppd.

Terrific Buy! American Made!

OPAQUE PROJECTOR

Projects illustrations up to 3" x 3½" and enlarges them to 4 ft. wide. No film or negatives needed. Projects charts, diagrams, pictures, photos, lettering in full color or black-and-white. Operates on 115-volt a.c. current, 6' extension cord and plug included. (Operates on 60-watt bulb, not included.) Size 12" x 8" x 4½" wide. Weight 1 lb., 2 oz. Plastic case with built-in handle.

Stock #70,199-Y.....$7.95 ppd.

EDMUND SCIENTIFIC CO.

SALE! TERRIFIC WAR-SURPLUS BARGAINS!

AERIAL CAMERA LENSES

Big variety . . . at a fraction of Gov't. cost! f/6, 24″ f.l., with diaphragm and lens cone. Used. Weight 25 lbs.
Stock #85,059-Y..$39.50 f.o.b. Utah

Same as above, but new. Weight 25 lbs.
Stock #85,060-Y..$59.50 f.o.b. Utah

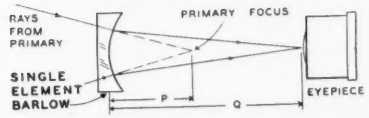
f/8, 40″ f.l., no mount or shutter. Weight 6¼ lbs.
Stock #70,186-Y.....$49.50 ppd.

f/5.6, 20″ f.l., telephoto with shutter and diaphragm. Weight 6¼ lbs.
Stock #70,187-Y.....$65.00 ppd.

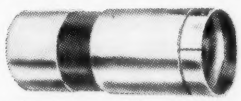
f/4.5, 6⅜″ f.l., with shutter and diaphragm. Weight 1 lb., 6 ozs.
Stock #70,189-Y.....$24.50 ppd.

These lenses are being successfully used for wide-aperture Moonwatch telescopes to see the small and fainter satellites. For eyepiece use our GIANT ERFLE.

DOUBLE AND TRIPLE YOUR TELESCOPE'S POWER WITH A BARLOW LENS



WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to short focal length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power. The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q.



Beautiful chrome mount. We now have our Barlow lens mounted in chrome-plated brass tubing with special spacer rings that enable you easily to vary the power by sliding split rings out one end and placing them in other end. Comes to you ready to use. Just slide our mounted lens into your 1¼″ I.D. tubing, then slide your 1¼″ O.D. eyepieces into our chrome-plated tubing. Two pieces provided, one for regular focal length eyepieces and one for short focal length ones.
Stock #30,200-Y Mounted Barlow lens.....$8.00 ppd.

UNMOUNTED 3X BARLOW LENS

These lenses are made for telescopes that have smaller diameter eyepieces than the standard 1¼″ size. Mount one between the eyepiece and objective, and triple your power. Instructions included. Single-element lens, focal length −1-5/16″, unmounted.
Stock #30,185-Y....0.932″ diam.....$3.50 ppd.
Stock #30,328-Y....0.912″ diam.....$2.50 ppd.

3X ADJUSTABLE-DIAMETER BARLOW LENS

For telescopes with eyepieces smaller than the standard 1¼″ outer-diameter size. Prongs on mount can be opened or closed to fit tubes from 13/16″ to 1″ outer diameter. Directions for using included.
Stock #30,339-Y....$5.00 ppd.

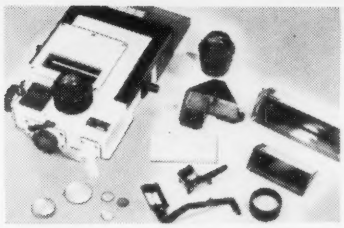
8″ SETTING-CIRCLE SET

Stock #50,133-Y..Complete set ..... **$3.00 ppd.**
Stock #60,078-Y..360° declination circle only **$1.60 ppd.**
Stock #60,079-Y..24-hour right-ascension circle only **$1.60 ppd.**

5¾″ SETTING-CIRCLE SET

Stock #50,190-Y..Complete set ..... **$2.50 ppd.**
Stock #60,080-Y..360° declination circle only **$1.35 ppd.**
Stock #60,081-Y..24-hour right-ascension circle only **$1.35 ppd.**

SPECIAL SALE OF OPTICAL PERISCOPES



We made a lucky buy, so here is another famous Edmund war-surplus bargain. It is a $500.00 tank periscope with over $200.00 worth of optics in it for only $18.00 postpaid. At one spot, you look through and see up and out of the prisms at unit power; or you can look through the built-in telescope system and see a wide-angle view at 6x. Simply remove the top prism and you have an 11°.3 6-power satellite telescope. *Brand new in original packages.* Over-all size is 14″ long by 7″ wide by 2½″ deep.

Now just for the bit of work involved in disassembling, you get a treasure-trove of precision optical parts for only $18.00. Glance at this list of parts and you'll realize what a value we are offering. You get a wide-angle Erfle eyepiece with a full 68° field and 1¼″ focal length. This is the same eyepiece used in Moonwatch telescopes, our Stock No. 5160. Also included are a 38-mm.-diam. collimator lens, 131-mm. focal length; 48-mm.-diam., mounted, coated objective lens, 189-mm. f.l.; prism cluster containing two light flint glass right-angle prisms (A, 41 mm.; B, 91 mm.; C, 64 mm.; and A, 41 mm.; B, 57 mm.; C, 40 mm.); two mounted right-angle prisms (A, 23 mm.; B, 34 mm.; C, 23 mm.; and A, 40 mm.; B, 42 mm.; C, 30 mm.); two silvered tank prisms (A, 102 mm.; B, 53 mm.; C, 38 mm.; and A, 167 mm.; B, 69 mm.; C, 49 mm.). (*See our catalog for explanation of these prism sizes.*) Also some other optical elements and reticles. Every amateur will find this a real value. Don't wait — order today. The last time we had these they sold for $30.00 — now on sale at only $18.00.

Stock #70,227-Y.....$18.00 ppd.

EQUATORIAL MOUNT and TRIPOD with CLOCK DRIVE

Heavy-duty mount. Drive operates on 110-volt, 60-cycle, a.c. house current. Follows motion of stars smoothly. 32″ tripod legs included.
Stock #85,081-Y.....$76.50 f.o.b. Barrington, N. J.

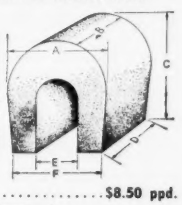
Same mount as above, without clock drive, for 8″ or smaller reflectors and for 4″ or smaller refractors.
Stock #85,023-Y.....New Low Price.....**$39.50** f.o.b. Barrington, N. J.

8-POWER ELBOW TELESCOPE

War Surplus — Amazing Buy!
$200 Gov't. Cost—Only $13.50

Big 2″ objective, focusing eyepiece 28-mm. focal length, Amici erecting system, turret-mounted filters of clear, red, amber, and neutral, reticle illumination. Sparkling, clear, bright image — 6° field (325 ft. at 1,000 yards). Focus adjusts 15 ft. to infinity. Eyepiece alone, 28-mm. focal length, is worth more than $12.50.
Stock #70,173-Y.....$13.50 ppd.

GIANT MAGNETS! TERRIFIC BARGAINS!



War Surplus — Alnico V type. Horseshoe shape. Tremendous lifting power. 5 lb. size. Its dimensions: A — 3¼″; B — 2¾″; C — 4-3/16″; D — 1¼″; E — 1¼″; F — 2⅜″. Strength is about 2,000 gauss. Will lift over 125 lbs.
Stock #70,183-Y.....$8.50 ppd.

15¾-lb. size magnet. Approximately 5,000-6,000-gauss rating. Will lift over 250 lbs.
Stock #85,088-Y.....$22.50 f.o.b. Barrington, N. J.
Shipping wt. 22 lbs.

Mounted Ramsden Eyepieces

Standard 1¼″ Diameter

Our economy model, standard-size (1¼″ O.D.) eyepiece. We mounted two excellent quality plano-convex lenses in black anodized aluminum barrels instead of chrome-plated brass to save you money. The clear image you get with these will surprise you. Directions for using short focal length eyepieces are included with both the ¼″ and ½″ models.
Stock #30,204-Y....¼″ focal length....$4.75 ppd.
Stock #30,203-Y....½″ focal length....$4.50 ppd.

"MAKE-YOUR-OWN" 4¼″ MIRROR KIT

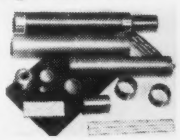
The same fine mirror as used in our telescopes, polished and aluminized, lenses for eyepieces, and diagonal. No metal parts.
Stock #50,074-Y.....$16.25 ppd.

GIANT ERFLE EYEPIECE

Here is an exciting bargain. We have obtained a large lot of these eyepieces reasonably — so down goes the price to $9.95 for a real sale. Lens system contains 3 coated achromats over 2″ in diameter. Gov't. cost over $100.00. Brand new, weight 2 pounds. The value will double when this lot is all sold, and triple and quadruple as years pass. If we didn't need to reduce our inventory, we'd be tempted to hold onto these eyepieces. Their wide apparent field is 65°. The focal length is 1½″. Lenses are in a metal cell with spiral threads; focusing adapter with 32 threads per inch is included; diameter is 2-11/16″. If you don't order now and you miss out on a hundred-dollar eyepiece for only $9.95, you can't say that we didn't try to impress you with its value. You can make some super-duper finders with these eyepieces. They are also ideal for rich-field telescopes, which are becoming more popular daily, particularly in the Sputnik age.
Stock #50,178-Y.....$9.95 ppd.

Attention! For Beginners, Junior Astronomy Clubs, Boy and Girl Scouts, Camp Groups, School Science Clubs

MAKE 8-POWER ASTRONOMICAL TELESCOPE with Low-Cost Beginner's Kit!

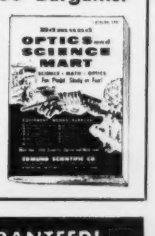


Every boy and girl of today dreams of being a part of the exploration of outer space. That desire makes building his own telescope a real thrill. Now anyone of Cub Scout or Brownie age on up can make his own astronomical 8-power telescope in one evening, without tools or machinery. Here is an ideal, attractive group project for scouts, junior astronomy clubs, or similar groups. (See special quantity prices.) Scope is powerful enough to show craters of the moon, Jupiter's satellites, and many stars not visible to the naked eye. Kit includes objective lens, field lens, eye lens, glare stops, kraftboard tubes, cadmium-plated metal ferrules, and other parts to build an 18″-long, 1¾″-diameter telescope of 8 power.
Stock #70,238-Y.....$3.00 ppd.

SPECIAL QUANTITY PRICES
Stock #70,239-Y.... 5 kits.....$12.50 ppd.
Stock #70,240-Y....10 kits.....$22.50 ppd.

BE SURE TO GET FREE CATALOG "Y"

128 Pages! Over 1000 Bargains!



Fantastic variety — never before have so many lenses, prisms, optical instruments, and components been offered from one source. Positively the greatest assembly of bargains in all America. Imported! War Surplus! Hundreds of other hard-to-get optical items. Many science and math learning and teaching aids.
Write for Free Catalog "Y."

ORDER BY STOCK NUMBER . . . SEND CHECK OR MONEY ORDER . . . SATISFACTION GUARANTEED!

BARRINGTON • NEW JERSEY

FIRST STEP TO FINER PERFORMANCE!

Easy, Low-Cost Way To Enjoy Thrills Of Astrophotography

Convert your present 35-mm. camera with this new adapter

Developed by Criterion especially for single-reflex 35-mm. cameras with interchangeable lens. Simply remove present lens mount and add this precision-made achromatic lens that adapts camera to eyepiece of any telescope — refractor or reflector. When ordering, *be sure to specify make of your camera.*

For 35-mm. cameras with SCREW-TYPE lens mount
Cat. #CPA-36 for 1¼" eyepiece holders..**$19.00**
Cat. #CPA-37 for 4" standard Dynascopes **$17.50**

For 35-mm. cameras with BAYONET-TYPE lens mount
Cat. #BPA-36 for 1¼" eyepiece holders..**$22.50**
Cat. #BPA-37 for 4" standard Dynascopes **$21.00**

New!

Dyn-o-Astro 35-mm. Camera

at less than regular price of camera alone!

No need to be an expert photographer to take exciting astrophotos with this *single-reflex*-type, precision-made 35-mm. camera. No complicated settings. No plates or filmholders to load and unload. No worries about missing target. Large focusing screen shows you *exactly* what you are shooting, right up to moment you take the picture. Includes such advanced features as:

- — No accidental double exposures. Winding knob automatically advances film, positions mirror, winds shutter, counts exposures.
- — Dual-speed setting knob controls both fast and slow shutter speeds. Color coding makes mistakes impossible.
- — Integrated magnifier for critical focusing even on dim objects.

Takes time exposures and also has speeds up to 1/500 second. Guaranteed for 2 years. Complete, ready for use.

Model CP-35 fits 1¼" eyepiece holder **$89.00 postpaid**

Model CP-36 fits all standard 4" Dynascopes **$85.00 postpaid**

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Cat. #CS-47 to fit all 4¾" O.D. tubes..**$18.95**
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Paraboloidal Mirrors

The most important part of a reflector telescope is the precisely figured mirror. A mirror with a spherical surface suffers from spherical aberration, so it must be altered to a paraboloid to focus all the light rays in each bundle to the same point. Considerable skill is required to parabolize a fine mirror properly. Criterion Custom mirrors are made of the best pyrex glass, selected for freedom from internal stress and strain, and of the correct thickness for each size, parabolized by craftsmen and tested by Ronchi and Foucault tests, as well as by diffraction rings and resolution of double stars. They are aluminized and overlaid with zircon quartz. Each is guaranteed unconditionally, and to perform to the limit of resolution for its size.

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8" pyrex, f.l. approx. 64"	**$89.00**
10" pyrex, f.l. approx. 80"	**$179.00**
12" pyrex, f.l. approx. 96"	**$275.00**

A tolerance of 5% in focal length is customary. A deposit of ⅓ is required with orders for 8" to 12" mirrors.

Reflecting Telescope Mirror Mounts

Mounting the mirror to your scope correctly is most important. Criterion mounts are especially well designed, and are made of cast aluminum with brass mounting and adjustment screws. One section fits tube, other section holds mirror. Alignment accomplished by three spring-loaded knurled adjusting nuts. Outer cell designed to fit into or over your tube. Sufficient space left between the two cells. All drilled and tapped. Complete with holding clamps, springs, nuts, etc. Ready for use. Will prevent vibration and hold alignment once set. Will hold mirror without distortion of surface figure.

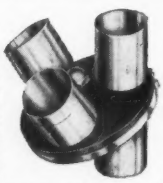
3"	**$3.00**	6"	**$6.00**
4"	**3.50**	8"	**12.50**
5"	**4.00**	10"	**14.75**

Complete Eyepieces

Finest quality. They are precision machined, mounted in standard 1¼" outside diameter barrels: ⅞" O.D. also available at no extra cost. Can be taken apart for cleaning. Designed to give sharp flat field clear to edge.

Huygens 18-mm. f.l. (¾")	**$ 7.50**
Kellner 9-mm. f.l. (⅜")	**7.90**
Kellner 7-mm. f.l. (9/32")	**8.50**
Kellner 12.7-mm. f.l. (½")	**9.50**
Orthoscopic 6-mm. f.l. (¼")	**12.50**
Orthoscopic 4-mm. f.l. (5/32")	**14.50**

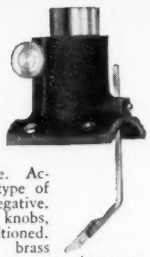
Revolving Turret



The Criterion Revolving Turret holds three eyepieces so that, as desired, the power of the telescope can be changed by merely turning the turret to a different ocular. Click stop insures positive and accurate positioning of each eyepiece. Turret holds eyepieces of standard 1¼" outside diameter. Fits into the holder of any refractor or reflector telescope that uses 1¼" eyepieces. Requires no alteration or adjustment and can be attached as easily as putting eyepiece into scope. Made of brass and aluminum with polished chrome-plated barrels.

Cat. #SRT-350.....**$14.50**

Rack-and-Pinion Eyepiece Mount



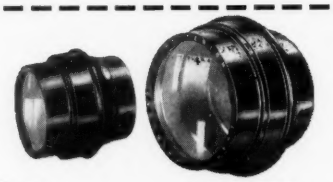
The most mechanically perfect focusing is by rack and pinion. This mount takes standard 1¼" eyepieces. Full 3½" of travel — more than ever before. Accommodates almost any type of eyepiece — positive and negative. Two knurled focusing knobs, variably tensioned and positioned. Solid cast-metal sliding brass tube — close tolerance prevents looseness. Mount aligns itself to any type tube. Four mounting holes, nuts and bolts included. Eye mount has square-rod-type diagonal holder which prevents loose alignment and vibration. Rod tempered to minimize temperature changes. Adjustable for 3" to 8" scopes, also 12" scopes if so specified at no extra cost. Order one or more of the complete eyepieces described below at the same time you send for this rack-and-pinion device, which accommodates any of our eyepieces perfectly.

Cat. #SU-38 **$7.95 postpaid**

New Model Eyepiece Mount

Same features as above but has wider base that is contoured to match the curve of a 7" to 8" diameter tube. Makes professional appearance. Furnished without Diagonal Rod #SU-9R **$9.95**

Diagonal Rod — Cat. #SU-9R.....**$1.00**



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- Air-spaced to very critical optical formula.
- Magnesium-fluoride coated on all surfaces for maximum light transmission.
- Cell engraved with effective focal length and completely threaded.
- Sunshade extension with dewcap on all sizes.

Cat. #	Clear Aperture	Focal Length	Price
S-210	60 mm. (2.4")	910 mm. (35.8")	**$19.95**
S-220	3"	1250 mm. (49.2")	**52.00**
S-230	4"	1600 mm. (62.9")	**95.00**

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Criterion 4-vane diagonal mountings are fully adjustable, will hold elliptical diagonals in perfect alignment. Made of brass, chemically blackened. Precision adjusting screws center flat and vary its angle so that primary and secondary mirrors can be set in perfect alignment. Thin vanes with special adjustable studs.

Cat. #	Minor-Axis Size	For Tubes	Price
S-51	1.25"	6½" to 7½"	**$10.00**
S-52	1.30"	6½" to 7½"	**10.00**
S-53	1.50"	8½" to 9½"	**10.00**
S-54	1.75"	9½" to 10½"	**12.50**
S-55	2.00"	11" to 11½"	**14.95**
S-56	2.50"	Specify tube I.D.	**19.95**

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CONDUCTED BY ROBERT E. COX

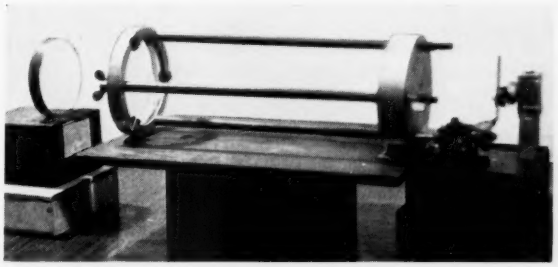
An English Catadioptric Telescope

COMPLETION of my 6-inch Gregory-Maksutov telescope has provided me with an instrument of unsurpassed performance, and there is no doubt left in my mind as to the superiority of the catadioptric system over the conventional Newtonian reflector.

The procedures I used to control radii during grinding were described in this department in April, 1959 (page 350). All three surfaces were brought to sphericity by the normal knife-edge testing method. Although the short radii of the lens surfaces were difficult to work with, I had success with a mixture of the Foucault and Ronchi tests. As shown on page 124, an excellent picture of the surface characteristics can be obtained by projecting Ronchi bands on a ground-glass screen. It is difficult to place the eye in the proper position for the knife-edge test unless the off-axis or beam-splitter method is used.

Final figuring of the system was controlled by autocollimation against an optical flat. The lens and mirror, mounted in aluminum cells, were aligned for testing by means of the three slender tubes shown in the photograph. Later, this same assembly was covered with sheet iron to make up the telescope tube itself, so the final collimation during testing was not disturbed. It was necessary to aspherize the primary mirror slightly to reduce a small amount of overcorrection, but this was managed without difficulty.

The fork-type mounting, made of welded aluminum, has an electric synchronous-motor drive in right ascension. But since the field of the f/23 system is small, a fine adjustment has been added in declination,



Jack Youdale used this autocollimation arrangement for testing his f/23 Gregory-Maksutov telescope. Though displayed here horizontally, in practice the components were placed in a vertical position. The optical flat is at the left.

The testing jig shown above was covered with sheet iron to form the tube for Mr. Youdale's catadioptric instrument. The fork-type mounting is made of aluminum. It has an electric drive in right ascension and a slow-motion control in declination (seen along the fork arm). The ease with which a Maksutov telescope can thus be mounted is well illustrated here. Photographs by the author.

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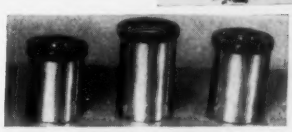
Holds 3 standard 1¼" O.D. eyepieces. Smooth turn to grooved notch aligns eyepiece precisely, ready to focus for various powers. Suitable for reflectors or refractors. **$15.75**



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6. Accurately ground and polished steel axles, extra-long bearings and large brakes provide free movement and precise control.
7. Sturdy, cast-aluminum, tapered channel legs open to fixed position, require no folding braces. Close easily for carrying.

SPECIFICATIONS: Heavy-duty saddle, tube clamp, axle bearings, rotating base, tripod top, tapered channel legs, and extra pier top are cast aluminum. Axles are 1¼" ground and polished steel. Bearings are 5½" long. Large-area brakes, knurled bronze-aluminum alloy adjusting knobs. Brass thrust washers at all friction points. Knurled knobs lock rotating base in V groove in tripod top, release for easy transfer to permanent pier. Latitude is adjustable 0° to 55°. Latitude bolt, leg bolts, nuts, washers cadmium plated. Weight 23 lbs.

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EQUATORIAL MOUNT Complete, for 7" tube	$ 79.50	f.o.b.
Without legs	69.50	"
Complete, for tubes to 9" x 60"	89.75	"
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Pier top for permanent mount	5.95	"
COUNTERWEIGHT 12½ lbs.	4.95	"
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1¼" EYEPIECE HOLDER	7.95	"
SETTING CIRCLES 1" to 2" bore. (Specify shaft diameter) Per pair	12.75	"
COMPLETE PARTS and instructions for building the 6" Cleveland, except optical parts	129.75	f.o.b.
6" PYREX MIRROR f/8 1/10 wave, parabolic, beryllium coated, with matching 1/10 wave, 1.25" x 1.77" diagonal	67.50	ppd.

Add 3% sales tax on Ohio orders.

COUNTERWEIGHT Lead and antimony. 3¾" diam. x 3" with 1" or 1¼" bore. Weight 12½ lbs.

TELESCOPE TUBE Extruded aluminum. 7" O.D. x 0.072" wall x 60" length. Not machined.

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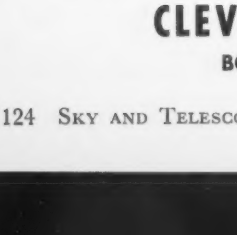
6" MIRROR CELL Solid plate protects mirror. Ring housing reduces convection currents. Improved clips hold mirror without pressure. Shockproof, cushioned adjustments prevent vibration, keep mirror in collimation. No springs. Cast aluminum, machined for 7" O.D. tube.

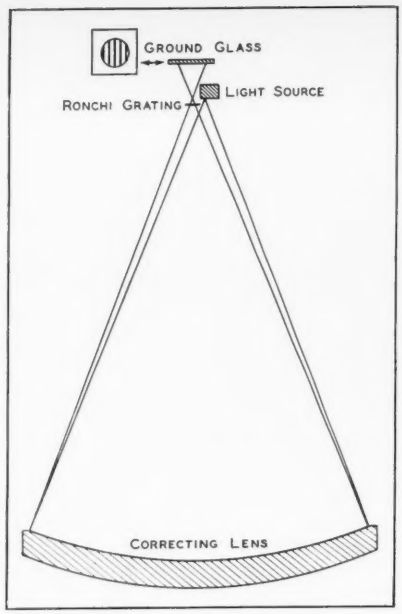
DIAGONAL HOLDER Fully adjustable, shockproof design. One turn moves mirror position 0.050". Three screw adjustments give you perfect control of mirror angle, make collimating easy. Made for 1¼ x 1¾ elliptical or rectangular mirrors, or 1¼" prisms, tubes up to 10". Specify mirror type, size, and tube I.D. when ordering.



1¼" EYEPIECE HOLDER Acme-threaded brass sleeve in accurately machined, cast-aluminum housing gives you smooth, micrometer-sharp focusing. One turn moves eyepiece 0.125". Stays where you set it. Only one moving part.

CLEVELAND ASTRONOMICS

BOX 209, CHAGRIN FALLS, OHIO



The Ronchi testing setup used by Mr. Youdale for determining the characteristics of his correcting-lens curves.

to aid in centering objects. It consists of a lever driven by a fine screw, providing sufficient movement for the purpose. A clamping screw on the collar attached to the declination axle allows rapid setting of the telescope in this co-ordinate.

This Maksutov is, I believe, the first completed in England by an amateur, although one or two others are under construction. Working the optics by hand in one's spare time is a long slow job, but the result is worth it. Eventually, I expect to make another Maksutov of 10-inch aperture, a convertible type for both prime-focus photography and visual observing at the Cassegrainian focus.

JACK YOUDALE
21 Stanhope Rd.
Billingham, Durham
England

A FLAT-ROOF OBSERVATORY

IF AN AMATEUR intends to do most of his observing at a fixed location, he can mount his instrument on a permanent pier and place a building around it. With only limited funds for such a project, I have solved my observatory construction problem by means of a simple design and the exclusive use of wood.

First, a hole was dug in the ground about 10" in diameter and 48" deep. In it was placed a 6' piece of 4"-by-4" lumber, the part underground protected by creosote, and the space around the post was filled with concrete. Before the mixture set, one side of the post was aligned along a north-south line and it was carefully plumbed to the vertical.

Afterward, I decided that the pier was too short for comfortable observing with my reflector, and added a 5" block to the

Wallace E. Harris' flat-roof observatory opened and ready for use.

top of the post by means of a long heavy screw. Only after the equatorial mounting was perfectly aligned in azimuth did I tighten the screw permanently. Since few mountings have provision for adjustment in azimuth, this feature of the pillar is a great aid.

The base of the mounting has holes that fit onto headless ¼″ bolts set 2″ deep into the top of the block. The mounting is easily slipped over them and fastened with large wing nuts. When the telescope is to be used as a portable, the wing nuts make it easy to transfer the mounting to a tripod.

Although a building 5′ or 6′ square would do for my instrument, I decided on one 8′ square to give more room and to allow for a possible larger instrument in the future. The pier is in the center of the floor, which does not touch the post, but insulation under the floor fills the central gap and prevents air from entering. The isolation of the pier is so complete that jumping on the floor does not vibrate the telescope.

The building framework is of 2-by-4's, with 8″-wide siding. The door, 2′ wide, is at the junction of the north and east sides.

Perhaps most unusual is the roof, which has two sections that overlap when closed, two strips of 1″-by-1″ wood making a weatherproof seal. One piece is placed on the upper side of one section, the second on the lower side of the other. Each section is made of a 4′-by-8′ sheet of ¼″ weatherproof plywood, with stiffening members along each edge and across the middle. These roof sections overlap the walls for protection from the weather.

The roof sections are hinged at the top of the north and south walls, and supporting braces hold the corners when they are opened for observing. My horizon is obstructed by neighboring objects, so there is no point in lowering the roof sections until they are horizontal. Set at the angle shown in the picture, they act as light and wind screens, and are easier to raise when the observatory is being closed. The braces are hinged, automatically dropping to the proper positions on the ground when the roof is opened and folding back against the top when it is closed.

A 2″-by-2″ brace is fastened by hinges

Here the observatory is closed. Note how the two roof sections overlap one another and the side walls, thus insuring weathertightness. The building has sides eight feet long. Photographs by Mr. Harris.

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near the center of each roof section along the inside edge, to act as a center support when the roof is closed and as a handle for opening and closing the section. While the plywood roof sections are not actually heavy, they are a little awkward to handle, and for a larger shelter of this design the sections should be counterweighted.

The inner corners of the observatory have chart shelves that also serve as seats for visitors. Heavy door latches on the inside walls lock the roof, while a hasp and padlock are used outside the door.

This observatory has been very satisfactory. The viewing position is always dry, and the shelter is a great convenience on windy nights.

WALLACE E. HARRIS
298 Broad St.
Eatontown, N. J.

PROPER LOCATION FOR A NEWTONIAN DIAGONAL

MANY amateur-made reflectors do not have perfect optical centering, due to the failure of their makers to include a small correction to the position of the diagonal mirror — a slight shift sideways in the tube and away from the eyepiece. This adjustment is described in Allyn J. Thompson's *Making Your Own Telescope,* page 117, and in SKY AND TELESCOPE for May, 1955, page 297. However, no formula for the amount of offset is given in either place.

While D. F. Brocchi long ago presented a method for calculating the offset, in *Popular Astronomy,* he assumed that the image plane is a point, and he did not consider a real field. Hence he obtained a displacement slightly too large.

As described in more detail in *Thru-the-Eyepiece,* a publication of the Great Plains Astronomical Society, I have derived the following formula for the amount of offset, d, in the direction away from the eyepiece:

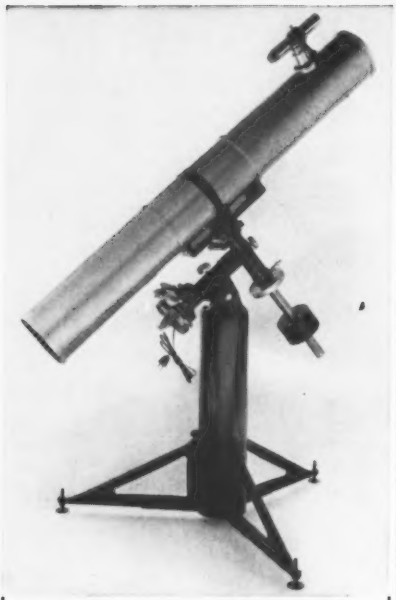
$$d = a(D - a)/4(F - c),$$

where a is the minor axis of the diagonal, D the working diameter of the primary and F its focal length, and c the distance from the center of the diagonal to the primary focal plane.

This displacement has nothing to do with the selection of the diagonal size (a subject adequately covered in *Making Your Own Telescope* on page 91), and is calculated afterward. The formula is actually a very close approximation, its error not exceeding 0.0001″ for an 8-inch, f/7 reflector. In this case, if a is 1.37″ and c 7″, the offset will be 0.046″.

To obtain perfect centering, the flat should also be moved slightly toward the primary mirror. However, this is automatically taken care of when the diagonal is collimated with respect to the outline of the bottom of the eyepiece adapter tube.

KELVIN MASSON
338 Plaza Ave.
St. Louis 35, Mo.



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New 1.25″ **SKY-MICRO** mount with exclusive MICRO-VERNIER action (focus to 1/10,000″) ● 360° rack and pinion (generated) ● Safety stops on both tubes ● Removable contoured base ring (specify tube diam., or if "flat" base wanted) ● Adjustable bronze bushings ● Phenolic drag ● Diagonal boss ● Beautiful black and grey finish ● All metal construction ● Hardware, instructions.
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The PAR Jr. Equatorial Mount

The rugged PAR Jr. Equatorial Mount is designed to give utmost rigidity at the points of greatest stress (note tapered aluminum housings). Includes latitude adjustment, large knurled locking screws and close-tolerance machined bearings with ¾″ chrome-plated precision-ground steel shafting. Base of mount is fully rotatable for altazimuth viewing and can be quickly disassembled from the tripod. Steel legs fold for easy portability. Mount has black wrinkle primer and 3-dimensional space blue marbleized finish. State tube O.D. and approximate scope weight, as custom-made saddle and proper counterbalance are included.

The PAR Jr. Mount . . . $29.50
Shpg. wt., approx. 20 lbs. f.o.b. Candor, N. Y.

We unconditionally guarantee the PAR Jr. Equatorial Mount to be exactly as described and illustrated, and to surpass even your greatest expectations, or return it and your money will be refunded promptly. Send your order today for immediate delivery. C.O.D. orders accepted with one-half payment.

VERNONscope & Co.
Candor, New York

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MOUNTED AIR-SPACED TELESCOPE OBJECTIVES

3¼" (clear) DIAMETER

f/15—48" focal length { UNCOATED ..... $28.00 / COATED 32.00

4⅛" (clear) DIAMETER

f/15—62" focal length { UNCOATED ..... $60.00 / COATED 69.00

"THOSE WHO KNOW" BUY FROM US BECAUSE:
Each lens is thoroughly tested and guaranteed to resolve to Dawes' limit. They are corrected for the C and F lines (secondary chromatic aberration). The zonal spherical aberration and the chromatic variation of spherical aberration are negligible. The cells are machined to close tolerances so that they fit directly over or into our standard aluminum tubing, eliminating any mounting problems. Test a lens, or have any qualified person test it; we are certain that you will be satisfied. If not, take advantage of our money-back guarantee. *We offer the lowest priced, hand-corrected, precision, American-made astronomical objective,* mounted in an aluminum cell. Our reputation for high-quality lenses has established us as the most reliable source in the industry.

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6" (clear) DIAMETER

Hard-coated on 4 surfaces

f/10—60" focal length { MOUNTED ..... $175.00 / UNMOUNTED 150.00

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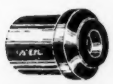


Mounted Eyepieces

The buy of a lifetime at a great saving. Perfect war-surplus lenses set in black-anodized standard aluminum 1¼" O.D. mounts.

F.L.	TYPE	PRICE
6 mm. (¼")	Ramsden	$ 4.75
12.5 mm. (½")	Ramsden	4.50
12.5 mm. (½")	Symmetrical	6.00
16 mm. (⅝")	Erfle (wide-angle)	12.50
16 mm. (⅝")	Triplet	12.50
18 mm. (¾")	Symmetrical	6.00
22 mm. (27/32")	Kellner	6.00
27 mm. (1-1/16")	Kellner	4.50
32 mm. (1¼")	Orthoscopic	12.50
35 mm. (1⅜")	Symmetrical	8.00
55 mm. (2-3/16")	Kellner	6.00
56 mm. (2¼")	Symmetrical	6.00

COATED LENSES 75 cents extra.

"Giant" Wide-Angle Eyepieces

ERFLE EYEPIECE (65° field) contains 3 coated achromats. 1½" E.F.L., clear aperture 2⅛". Has a focusing mount with diopter scale. Will make an excellent 35-mm. Kodachrome viewer. Magnifies seven times ..... **$12.50 ppd.**

Same as above without diopter scale **$9.95**

1¼"-diam. Adapter for eyepiece above **$3.95**

WIDE-ANGLE ERFLE (68° field) **EYEPIECE.** Brand new; coated 1¼" E.F.L. Focusing mount. 3 perfect achromats, 1-13/16" aperture **$13.50**

1¼"-diam. Adapter for eyepiece above **$3.95**

WIDE-ANGLE ERFLE 1½" E.F.L. Brand new; contains Eastman Kodak's rare-earth glasses; aperture 2"; focusing mounts; 65° field **$12.50**

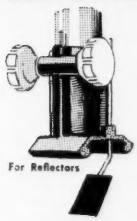
1¼"-diam. Adapter for eyepiece above **$3.95**

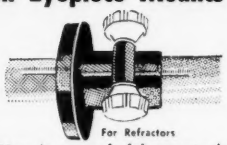
An Economical Eyepiece

This mounted eyepiece has two magnesium-fluoride coated lenses 29 mm. in diameter. It is designed to give good eye relief. E.F.L., 1¼". Cell fits 1¼" tube.

Coated **$5.90 ppd.** Not coated **$5.25 ppd.**

Rack-&-Pinion Eyepiece Mounts





Here is a wonderful opportunity for you to own a most mechanically perfect Rack-&-Pinion Focusing Eyepiece Mount with variable tension and adjustment. Will accommodate a standard 1¼" eyepiece, positive or negative. The body casting is made of lightweight aluminum with black-crackle paint finish, focusing tube of chrome-plated brass. Focusing tube for refractors has a travel of 4", for reflectors 2", and will fit all size tubing.

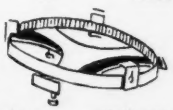
REFRACTOR TYPE for 2⅛" I.D. Tubing **$12.95 ppd.**
" " for 3¼" I.D. Tubing **12.95 ppd.**
" " for 4⅜" I.D. Tubing **12.95 ppd.**
REFLECTOR TYPE (less diagonal holder) **8.50 ppd.**
DIAGONAL HOLDER ..... **1.00 ppd.**

Astronomical Mirrors

These mirrors are of the highest quality, polished to ¼-wave accuracy. They are aluminized, and have a silicon-monoxide protective coating. You will be pleased with their performance.

	Diam.	F.L.	Postpaid
Plate Glass	3-3/16"	42"	$ 9.75
Pyrex	4¼"	45"	13.50
Pyrex	6"	60"	25.00

Mirror Mount



Cast aluminum. Holds all our mirrors firmly with metal clips. Completely adjustable. Assembled.

3-3/16" Mount fits our 4½" tubing..... **$4.00 ppd.**
4¼" Mount fits our 5" tubing..... **4.00 ppd.**
6" Mount fits our 7" tubing..... **6.50 ppd.**

GIANT "3" inch TELESCOPE

HIGH-POWER SCOPE AMERICAN MADE

40 POWER

ALL LENSES COATED

Big 3"-diameter, achromatic, coated objective will give you the brightest crystal-clear images. Micrometer spiral focusing drawtube, lightweight aluminum construction throughout, tough black crackle finish. Length open 22", closed 15½". Upright image. Guaranteed to perform flawlessly. **$57.50 ppd.**

TRIPOD FOR TELESCOPE ABOVE
Sturdy, lightweight, all-metal, black crackle finished tripod. Ball-swivel joint allows easy directional adjustments. Equipped with a standard ¼ x 20 stud which will fit any photo tripod. Stands 11" high, weight 1½ lbs. Comes with web straps. **$8.95 ppd.**

Special Coated Objective

BIG 2⅛" DIAM. — 40" F.L. — $6.00

These achromatic objective lenses are tested and have the same high quality as "Big Lenses" described below, except they are seconds for slight edge chips or small scratches only. Quality guaranteed. **ONLY $6.00 ppd.**

Coated Binoculars

Beautifully styled imported binoculars. Precision made.

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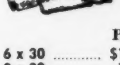
American Type

"Zeiss" Type

Complete with carrying case and straps. American type offers a superior one-piece frame and clean design.

Size	Field at 1,000 yards	Type	Center Focus	Ind. Focus
6 x 15	360 ft.	Opera	—	$12.75
6 x 30	395	"Zeiss"	$18.75	16.75
7 x 35	341	"Zeiss"	20.75	17.95
7 x 35	341	American	23.50	—
7 x 35	578	Wide-Angle 11°	35.00	—
7 x 50	372	"Zeiss"	24.95	22.50
7 x 50	372	American	32.50	—
8 x 30	393	"Zeiss"	21.00	18.25
10 x 50	275	"Zeiss"	28.75	26.75
20 x 50	183	"Zeiss"	33.75	31.75

All prices above plus 10% Federal tax.



Monoculars

Brand new, coated optics, complete with pigskin case and neck straps.

	Price		Price
6 x 30	$10.00	7 x 50	$14.75
8 x 30	11.25	16 x 50	17.50
7 x 35	12.50	20 x 50	20.00

8-Power Elbow Telescope

This M-17 telescope has a brilliant-image 48° apparent field — 325 feet at 1,000 yards. The telescope can be adjusted for focusing 15 feet to infinity. It has a 2" objective, focusing eyepiece 28-mm. focal length with an Amici erecting system. Turret-mounted filters: clear, red, amber, and neutral. Lamp housing to illuminate reticle for nighttime use. Truly the biggest bargain you were ever offered. Original Gov't. cost $200.

Not coated **$13.50 ppd.** Coated **$17.50 ppd.**

"BIG" ACHROMATIC TELESCOPE OBJECTIVES

We have the largest selection of diameters and focal lengths in the United States available for immediate delivery. These are perfect magnesium-fluoride coated and cemented Gov't. surplus lenses made of finest crown and flint optical glass. Not mounted. Fully corrected. Tremendous resolving power.

● We can supply ALUMINUM TUBING AND CELLS for the lenses below. ●

Diameter	Focal Length	Each
54 mm. (2⅛")	254 mm. (10")	$12.50
54 mm. (2⅛")	300 mm. (11.8")	12.50
54 mm. (2⅛")	330 mm. (13")	12.50
54 mm. (2⅛")	390 mm. (15.4")	9.75
54 mm. (2⅛")	508 mm. (20")	12.50
54 mm. (2⅛")	600 mm. (23½")	12.50
54 mm. (2⅛")	762 mm. (30")	12.50
54 mm. (2⅛")	1016 mm. (40")	12.50
54 mm. (2⅛")	1270 mm. (50")	12.50
78 mm. (3-1/16")	381 mm. (15")	21.00
80 mm. (3⅛")	495 mm. (19½")	28.00
81 mm. (3-3/16")	622 mm. (24½")	22.50
83 mm. (3¼")	660 mm. (26")	$28.00
83 mm. (3¼")	711 mm. (28")	28.00
83 mm. (3¼")	762 mm. (30")	28.00
83 mm. (3¼")	876 mm. (34½")	28.00
83 mm. (3¼")	1016 mm. (40")	30.00
102 mm. (4")	876 mm. (34½")	60.00
108 mm. (4¼")	914 mm. (36")	60.00
110 mm. (4⅜")*	1069 mm. (42-1/16")	60.00
110 mm. (4⅜")	1069 mm. (42-1/16")	67.00
128 mm. (5-1/16")*	628 mm. (24¾")	75.00
128 mm. (5-1/16")	628 mm. (24¾")	85.00

*Not coated

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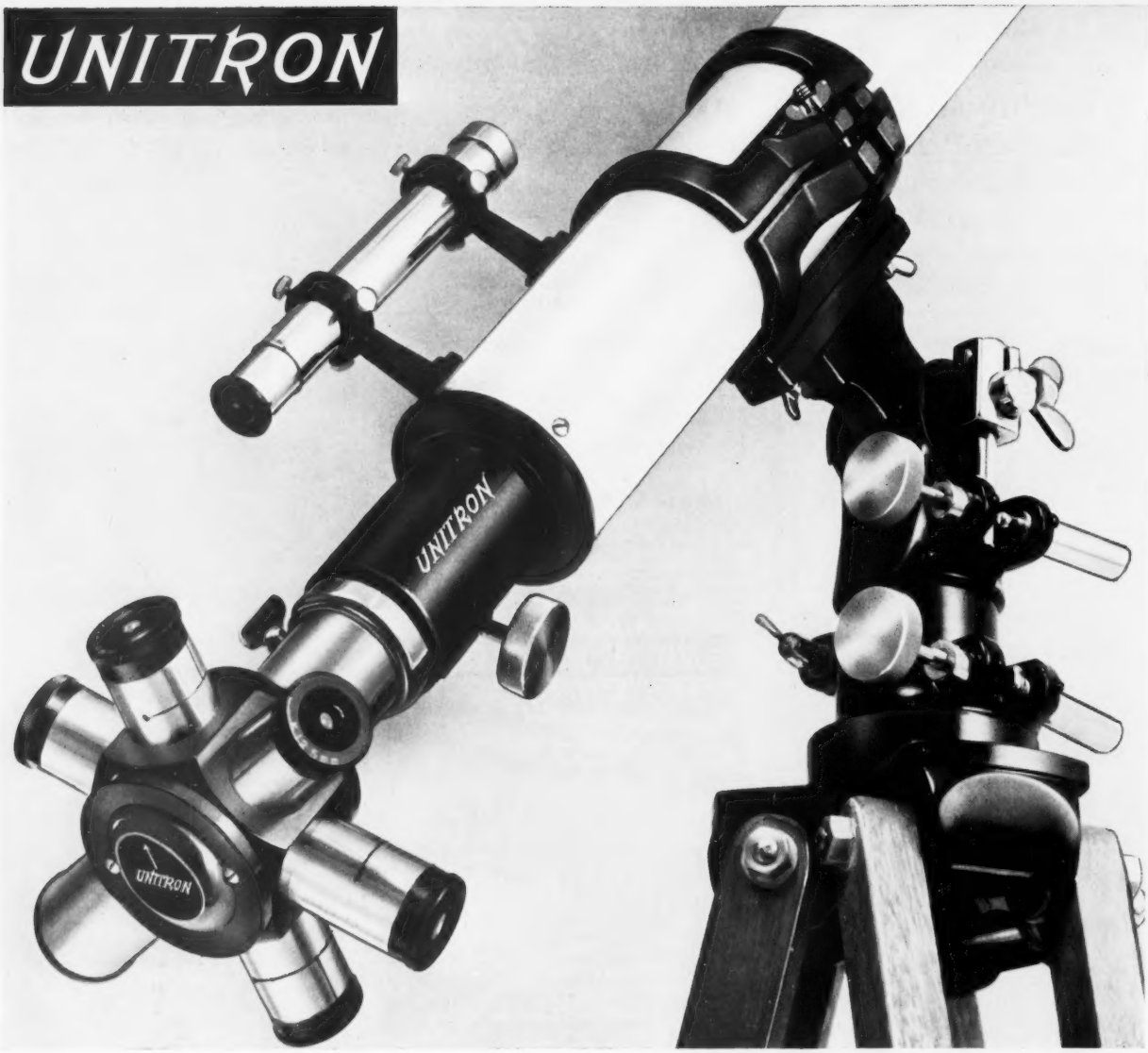

It takes only $12.50 down to own this UNITRON

Little wonder that the UNITRON 2.4" Altazimuth Refractor has long been America's most popular low-priced refractor.

For UNITRON and only UNITRON combines unexcelled optical and mechanical performance with exclusive features designed to increase your observing pleasure. As an example, take UNIHEX — the Rotary Eyepiece Selector which relieves you of the burden of fumbling with eyepieces in the dark. Or, perhaps your observing situation may call for the DUETRON Double Eyepiece, the erecting prism system, the Astro-Camera 220, or the sun screen.

Optically speaking, UNITRON Refractors duplicate the performance of larger telescopes of other types. Furthermore, there are no mirror surfaces to become tarnished, no secondary optics to cause diffraction patterns, and no folding of the light back on itself with consequent loss of definition. It is not surprising that you see more and see better with a UNITRON.

The UNITRON 2.4" Altazimuth Refractor is priced at only $125 complete with tripod, sturdy mounting with micrometric slow-motion controls, four eyepieces, carrying cases, and accessories. Using our Easy Payment Plan, a mere 10% down payment of only $12.50 brings this UNITRON to you.

With interest in astronomy at an all-time high, now is the time to treat yourself to a UNITRON. After all, you deserve the very best.

See the back cover.

UNITRON INSTRUMENT DIVISION of UNITED SCIENTIFIC CO.
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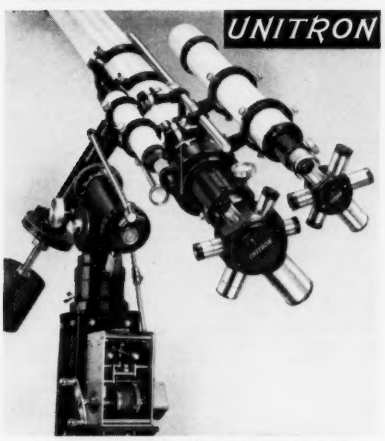
For year-round pleasure, give or get a UNITRON for Xmas

Consider These Favorites

UNITRON SATELLITE TELESCOPE



UNITRON 4" Photo-Equatorial

UNITRON 6" Photo-Equatorial

MANY Models To Choose From!

2" SATELLITE ($7.50 Down) 6x, diagonal eyepiece, altazimuth mount with circles, stand — **$75**

1.6" ALTAZIMUTH ($7.50 Down) with eyepieces for 78x, 56x, 39x — **$75**

2.4" ALTAZIMUTH ($12.50 Down) with eyepieces for 100x, 72x, 50x, 35x — **$125**

2.4" EQUATORIAL ($22.50 Down) with eyepieces for 129x, 100x, 72x, 50x, 35x — **$225**

3" ALTAZIMUTH ($26.50 Down) with eyepieces for 171x, 131x, 96x, 67x, 48x — **$265**

3" EQUATORIAL ($43.50 Down) with eyepieces for 200x, 131x, 96x, 67x, 48x — **$435**

3" PHOTO-EQUATORIAL ($55.00 Down) with eyepieces for 200x, 171x, 131x, 96x, 67x, 48x — **$550**

4" ALTAZIMUTH ($46.50 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x — **$465**

4" EQUATORIAL ($78.50 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x — **$785**

4" PHOTO-EQUATORIAL ($89.00 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x — **$890**

4" EQUATORIAL with clock drive **($98.50 Down)**, Model 160V, eyepieces as above — **$985**

4" EQUATORIAL with clock drive and metal pier **($107.50 Down)**, Model 166V, eyepieces as above — **$1075**

4" PHOTO-EQUATORIAL with clock drive and Astro-camera **($117.50 Down)**, with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x — **$1175**

4" PHOTO-EQUATORIAL with clock drive, pier, Astro-camera **($128.00 Down)**, eyepieces for 375x, 300x, 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x — **$1280**

6" EQUATORIAL with clock drive, pier, 2.4" view finder, with eyepieces for 625x, 500x, 416x, 357x, 277x, 200x, 138x, 100x, 62x, 42x — **$5125**

6" PHOTO-EQUATORIAL as above but with 4" guide telescope, illuminated diagonal, UNIBALANCE, Astro-camera Model 330 — **$5660**

6" PHOTO-EQUATORIAL as above with addition of 3" Astrographic Camera Model 80 — **$6075**

HOW TO ORDER

Send check or money order in full or use our Easy Payment Plan, as described below. Shipments made express collect. Send 20% deposit for C.O.D. shipment. All instruments are stock items and Christmas orders will be shipped the same day as received. For special rush orders and information, telephone HAncock 6-9878 (Boston exchange) and ask for "Christmas Order Department." UNITRON instruments are fully guaranteed for quality, workmanship, and performance, and must meet with your approval or your money back.

Use Our EASY PAYMENT PLAN

UNITRON's popular Easy Payment Plan is a convenient and economical way to buy your UNITRON Refractor when you do not want to disturb your savings or when you haven't the total cost of the telescope immediately available. The down payment required is 10%. The balance due is payable over a 12-month period, and there is a 6% carrying charge on the unpaid balance. Your first payment is not due until 30 days after you receive the instrument, and if you should want to pay the entire balance due at that time, the carrying charge is canceled. (6" models available on special plan.)

There is no "red tape" when you order — you merely fill in the UNITRON Easy Payment Order Form, return it together with the required down payment, and the model of your choice is shipped to you at once.

Do not hesitate to use this plan merely because you have never before purchased anything on time payments. The procedure is practically painless and is an ideal means of enjoying the use of your UNITRON while paying for it.

See the back cover.

Note These Unitron Features

- LENSES are FULLY CORRECTED for spherical and chromatic aberration and are COATED for maximum brilliance and clarity of image. Optics especially designed for astronomical observation. AIR-SPACED OBJECTIVES.
- REFRACTOR type of design duplicates the performance of larger telescopes of other types. No mirrored surfaces to become oxidized. Superior definition to the very edge of the field.
- EYEPIECES of the HIGHEST QUALITY: Orthoscopic, Achromatized Symmetrical, Kellner, Huygens. Three to ten eyepieces included with each instrument.
- FINEST MATERIALS used throughout. DURALUMIN TUBE. Moving parts of BRASS carefully machined to close tolerances, and finished in CHROMIUM. No war-surplus components used.
- MODERN DESIGN based on time-tested engineering principles. HANDSOME APPEARANCE to which no illustration can do justice.
- EQUATORIAL MODELS have slow-motion controls for **both** declination and right ascension as well as rapid-motion controls. Sturdy TRIPOD (or PIER).
- ALTAZIMUTH MODELS have slow-motion controls for **both** altitude and azimuth as well as clamps for both co-ordinates. Sturdy TRIPOD.
- VIEW FINDER with crosshair eyepiece.
- RACK-AND-PINION FOCUSING.
- Choice of UNIHEX Rotary Eyepiece Selector or STAR DIAGONAL and ERECTING PRISM for TERRESTRIAL OBSERVATION. The same complete range of terrestrial magnifications as for celestial observation.
- SUNGLASS for solar observation.
- ADDITIONAL ACCESSORIES available to add further to your observing pleasure.

Higher- and lower-power eyepieces available for all models. Prices include basic accessories, tripod and mounting, fitted wooden cabinets, and operating instructions.

Get UNITRON's FREE
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ASTRONOMICAL TELESCOPES

This valuable 38-page book is yours for the asking!

With artificial satellites already launched and space travel almost a reality, astronomy has become today's fastest growing hobby. Exploring the skies with a telescope is a relaxing diversion for father and son alike. UNITRON's handbook contains full-page illustrated articles on astronomy, observing, telescopes and accessories. It is of interest to both beginners and advanced amateurs.

Contents include—

- **Observing the sun, moon, planets and wonders of the sky**
- **Constellation map**
- **Hints for observers**
- **Glossary of telescope terms**
- **How to choose a telescope**
- **Amateur clubs and research programs**

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CELESTIAL CALENDAR

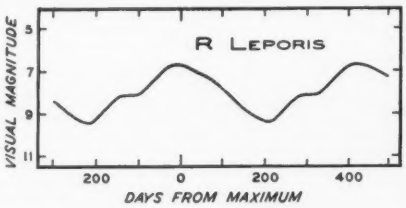
Universal time (UT) is used unless otherwise noted.

R LEPORIS

SOME dark December evening, when Orion is well up in the sky, look beneath it in the constellation Lepus for the very red variable R Leporis, scheduled to reach maximum light this month. The star is labeled in both the Norton and Skalnate Pleso atlases, at right ascension $4^h\ 57^m.3$, declination $-14°\ 53'$ (1950 coordinates).

R Leporis is one of the more erratic long-period variables. At intervals of from 13 to 15 months, it attains a maximum that has been anywhere between magnitudes 5.6 and 7.3. Its magnitude at minimum has been recorded from 8.1 to 10.5 in recent years. The accompanying average light curve, derived by the late Leon Campbell, shows a pronounced halt in the brightening of the star, several months before maximum.

R Leporis is noted for its intensely ruby color, making it one of the reddest stars in the entire sky within the range of small telescopes. Of spectral type N6e, it is four magnitudes fainter on blue-light photographs than to the eye. To appreciate better this star's unusual hue, examine it with the largest available telescope, as increased light grasp greatly enhances star colors.



The mean light curve of the long-period variable R Leporis, reproduced from "Studies of Long Period Variables," courtesy AAVSO.

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9¾" REFLECTOR telescope, 91", on equatorial mount. Slightly overparabolized. $125.00. Fred Jackson, Gustine, Tex.

PYREX MIRRORS: 6", 8", 10", made to order. $45.00, $75.00, $125.00, respectively. Donald O'Toole, 2100 Eye St., Apt. 3, Sacramento, Calif.

FOR SALE: 4" refractor, complete with equatorial mount and extras. First offer over $250.00. Jerry Burnett, 244 Ramble St., Hot Springs, Ark.

LOW-COST flats for amateurs. Northwestern Observatory, 6718 E. Seventh, Spokane 63, Wash.

METEORITES: Excellent for teaching, research, lectures, and demonstrations. $1.00, $2.00, $12.00, and $15.00. Scientific Laboratory, 2846 Oakley Ave., Baltimore 15, Md.

ALUMINUM TUBING: 17 sizes, 1" through 8". Pesco-A, Box 363, Ann Arbor, Mich.

FOR SALE: 2.4" equatorial refractor, slow motions, 5 eyepieces, Barlow, diagonal, erector, projection screen, new condition, $75.00. 6" reflector, f/7.5, equatorial mount, 1/16-wave mirror, 1/10-wave diagonal, Barlow, 2 eyepieces, 10x 42-mm. Unitron finder, new condition, $150.00. Joseph Frisch, 131 N. 2nd St., Coplay, Pa.

8" REFLECTOR, professionally figured, equatorial mount, slow motions, electric drive, finder, setting circles, 2 eyepieces, $400.00. Highly rated by professional observer on photographic results. Mrs. Grace Keys, W. 7th St., Dresden, Ohio.

SOUTHWEST OBSERVERS: Finest refractor telescopes — 2.4", 3", and 4" altazimuth and equatorial models shipped from Dallas, Texas. Terms and details on request. Melton Industries, 1901 Levee St., Dallas 7, Tex. Phone: RI 8-4769.

DUAL-slow-motion equatorial mounts. Mirrors. Refiguring. Special aluminum castings. John McQuaid, 2003 High, Logansport, Ind.

FIBERGLASS evercoat tubes. Attractive marproof finish. Blackened inside, great strength, durable, ⅛" wall. 7" inside diameter, to 60" lengths, approximately 5 pounds, $10.95. 9½" inside diameter, to 66" lengths, approximately 9 pounds, $17.95. f.o.b. Gardena. D. Fish, 2821 W. 147 St., Gardena, Calif.

FOR SALE: 10" Astrola, Skyscope, 3" refractor, miscellaneous accessories. Ronald Bales, 6030 Lake Labish Rd. N.E., Salem, Ore.

FOR THE PERFECT Christmas gift: f/10 4¼" parabolic mirrors, now pyrex, ground and polished to better than ⅛ wave, aluminized and quartz overcoated. $14.95. Matching diagonals for these mirrors, $2.95. Single-element mounted Barlow lenses: 0.946", $4.95; 1.250", $5.95. Finest wide-angle Kellner oculars: 0.946", 14-mm., $7.95; 1.250", 25-mm. (double achromat), $8.95. Unconditionally guaranteed. Vernonscope and Co., Candor, N. Y.

TELESCOPES, aluminum tubing, eyepieces. Write Peninsula Scientific, 2421 El Camino Real, Palo Alto, Calif.

FINE OPPORTUNITY for career in astronomical journalism for amateur or professional astronomer (man or woman) with physical science college degree, willing to learn business beginning with routine drafting and editorial work. Modest starting salary with annual increases. Box J, *Sky and Telescope*, Cambridge 38, Mass.

2.4" UNITRON altazimuth, one year old, $75.00. P. Britt, 82 Bret St., New Market, N. J.

164-PAGE photographic bargain catalogue listing thousands of photographic bargains. Send 25¢ for your copy, credited on first order. Central Camera Co., Dept. 26-C12, 230 S. Wabash Ave., Chicago 4, Ill.

PLANETARIUM LECTURER: Challenging position exists for a man interested in joining the staff of Boston's new Charles Hayden Planetarium. Previous planetarium experience helpful but not required. Send resume and salary requirements to Director, Charles Hayden Planetarium, Boston 14, Mass.

6" REFLECTOR, equatorial, extras. Good optics. $125.00. D. Grossman, Leverett H-43, Cambridge 38, Mass.

FOR SALE: 3.5" German refractor, equatorial, accessories, photos. T. Gosman, 32-59 43 St., Astoria 3, N. Y.

FOR SALE: 10" f/8 Newtonian telescope, built by Philetus Allen of Glens Falls, New York. Heavy equatorial mount weighs over 500 pounds. Synchronous-motor sidereal drive with speed-control motor coupled through differential. Motor-driven slow motion in declination. Excellent design and workmanship throughout. Complete detailed description on request. $1,500.00. H. Clifford Allen, Cherry Valley Rd., Princeton, N. J.

8" IMPROVED Fraunhofer objective, German made, mounted and coated, 2710-mm. focal length. $750.00 f.o.b. takes it. Payment by cash or by letter of credit to Gunter D. Roth, Theodolindenstrasse 6, Munich 9, West Germany.

FOR SALE: 4" Dynascope de luxe. Excellent condition. $40.00. Thomas Honker, 108 W. Carpenter St., Myerstown, Pa.

WANTED: High-quality research telescope; prefer 8" or 10" Maksutov, 6" or 7" refractor, 12" or 15" Cassegrainian, or equivalent. Good optics, ample circles, reliable drive, steady mount. Please submit full information to E. M. Weil, 3 Marion Ave., Albany 3, N. Y.

OCCULTATION PREDICTIONS

Observers in the Far West should watch the nearly full moon as soon as it rises on Sunday, December 13th, to view a late-afternoon occultation of the 1st-magnitude star Aldebaran (Alpha Tauri). As seen from station **K** (near Fresno, California), the star is covered by the dark edge of the moon at 4:30.7 p.m. Pacific standard time, about 25 minutes after the moon has risen and 17 minutes before sunset. Traversing a relatively short chord behind the southern part of the moon, the star will emerge at 5:00.7 p.m.

At places farther north, the duration of the occultation will be greater, and the eastern sky darker. For station **M**, north of Seattle, Aldebaran's immersion occurs about 28 minutes after sunset, and the emersion 54 minutes later in a dark sky.

To the south of station **K**, the chord of Aldebaran's travel behind the lunar disk becomes shorter, until the star just grazes the moon's southern edge.

December 13-14 **Alpha Tauri** 1.1, 4:33.6 +16-25.7, 14. Im: **K** 0:30.7 −0.3 −0.5 136; **M** 0:39.5 +0.2 +1.2 99. Em: **K** 1:00.7 +0.8 +3.2 200; **M** 1:33.8 +0.1 +2.0 238.

For stations in the United States and Canada, usually for stars of magnitude 5.0 or brighter, data from the *American Ephemeris* and the British *Nautical Almanac* are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degress and minutes, moon's age in days, immersion or emersion; standard-station designation, **UT**, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo**−**LoS**), and multiply **b** by the difference in latitude (**L**−**LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:
K +120°.0, +36°.0 **M** +123°.1, +49°.5

VARIABLE STAR MAXIMA

December 1, R Draconis, 163266, 7.6; 5, T Centauri, 133633, 6.1; 15, T Hydrae, 085008, 7.8; 18, V Monocerotis, 061702, 7.1; 19, R Leporis, 045514, 6.7; 22, R Bootis, 143227, 7.3; 26, R Leonis Minoris, 093934, 7.1; 26, RV Centauri, 133155, 7.6.

January 4, S Sculptoris, 001032, 6.8; 8, R Virginis, 123307, 6.9; 9, R Trianguli, 023133, 6.2.

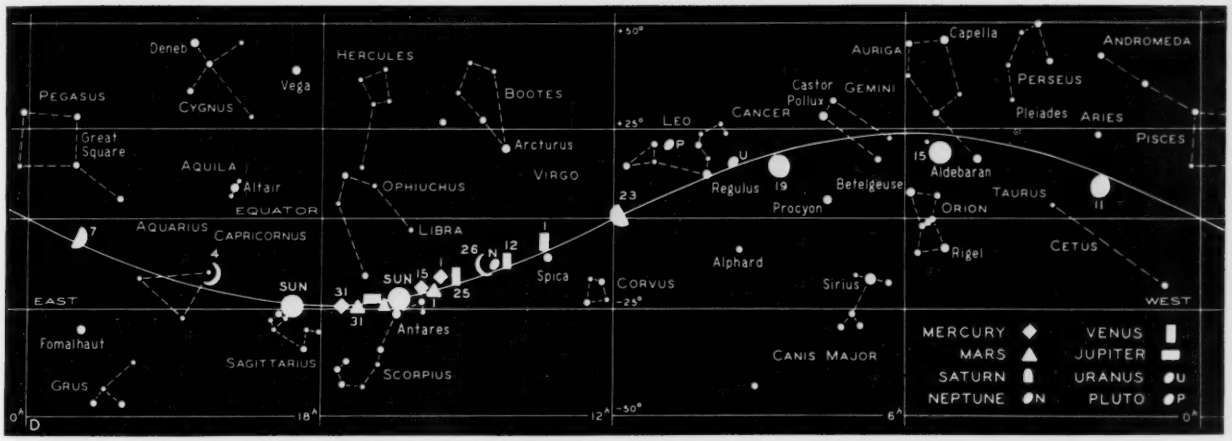
These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

MINIMA OF ALGOL

December 2, 6:10; 5, 2:59; 7, 23:48; 10, 20:37; 13, 17:26; 16, 14:16; 19, 11:05; 22, 7:54; 25, 4:43; 28, 1:32; 30, 22:21.

January 2, 19:10; 5, 16:00; 8, 12:49.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

Mercury will be favorably placed for observation for about 10 days before and nearly two weeks after it reaches greatest western elongation, 21° 03′ from the sun, on December 12th. Look for it in the southeastern sky just as dawn begins, rising about 1¾ hours ahead of the sun. On the 6th it will be south of Gamma Librae, forming a roughly equilateral triangle with Alpha and Beta Librae; then it moves eastward to a point just north of Beta in the Scorpion's head, by December 16th. Mercury's magnitude at elongation is −0.2, and in a telescope its disk is 62-per-cent illuminated and 6″.6 in diameter.

Toward the end of the month, Mercury takes part in a series of conjunctions, possibly visible in binoculars. On the morning of the 25th, the planet will pass about a degree north of Mars, with conjunction at 13^h Universal time. On the 27th there is an even closer approach to Jupiter, with Mars about a degree south of the pair. Then, on the following day, the slender crescent moon will pass about 5° north of the three planets.

Venus, in western Libra, is a brilliant morning-sky object this month. It rises about 3½ hours before the sun, its magnitude changing from −3.9 on the 1st of December to −3.6 on the 31st. On the 15th, its gibbous disk will be 65-per-cent illuminated and 18″.0 in diameter.

Earth reaches heliocentric longitude 90° on December 22nd at 14:35 UT, the time of the solstice. Winter commences in the Northern Hemisphere, summer in the Southern.

Mars rises during the dawn throughout the month, so this 2nd-magnitude planet is still invisible to the unaided eye. It may be detectable with binoculars when in conjunction with Mercury on December 25th, and when it is near Jupiter on the 29th.

Jupiter comes to conjunction with the sun on the 5th, but by the end of the month may be seen low in the southeast, rising about 1½ hours before sunup. Conjunction with Mercury will occur on December 27th, with Mars on the 29th.

Saturn may be viewed very low in the southwest at the beginning of December, setting about two hours after sundown. It soon becomes lost in the twilight glare, however, conjunction with the sun occurring on the 31st.

Uranus is a 6th-magnitude object in Leo, visible in binoculars. On the 15th it is at right ascension 9^h 33^m.7, declination +15° 15′ (1950 co-ordinates), rising about 2½ hours before midnight. Telescopically, the planet has a small, slightly greenish disk 3″.8 in diameter.

Neptune is near Spica in midmonth, at 14^h 25^m.3, −12° 35′ (1950), rising about 3½ hours before the sun. This 8th-magnitude planet is visible in small telescopes. Venus will pass less than a degree north of Neptune on December 14th, conjunction occurring at 16^h UT.

W. H. G.

DECEMBER METEORS

The full moon will seriously interfere with the maximum of the rich Geminids, on December 13th this year. This shower, however, is noted for its bright fireballs, which may be seen during a few days around the 13th.

Conditions will be somewhat more favorable for the Ursids, the moon being at last quarter; this shower reaches a sharp maximum at 5^h Universal time on December 23rd. Under normal conditions the predicted rate for the Ursids is 15 meteors per hour. However, the *Handbook* of the British Astronomical Association states that in 1959 there is an approximate repetition of the circumstances of the strong shower in 1945. Then a maximum hourly rate of 169 was reported during a display lasting four hours. Observers should watch for a possible recurrence this year.

W. H. G.

GIACOBINID METEOR REPORTS

As told on page 710 of the October issue, there was a possibility that the great Giacobinid meteor shower of 1933 and 1946 might recur on the night of October 9-10, 1959. But Comet Giacobini-Zinner, whose debris is responsible for these meteors, has changed its orbital motion appreciably since 1946, owing to a close approach to Jupiter. Hence it was uncertain if any shower would occur.

On October 9-10, at Aarhus, Denmark, A. V. Nielsen and two others watched from 19:15 Universal time to 3:45, but saw only about three meteors per hour. In Massachusetts, at the Agassiz station of Harvard Observatory, four observers looked for meteors between 3:45 and 6:00 UT. Only two objects were seen that could have come from the Giacobinid radiant, in Draco. In addition, G. S. Hawkins observed from Wayland and E. E. Epstein watched at Cambridge.

F. Pilcher, Topeka, Kansas, looked from 1:00 to 1:30 UT, but saw just one 4th-magnitude meteor, apparently a Giacobinid. Although all these observers had somewhat unfavorable weather conditions, apparently no meteor storm occurred, indicating the earth missed the main stream of meteoric particles.

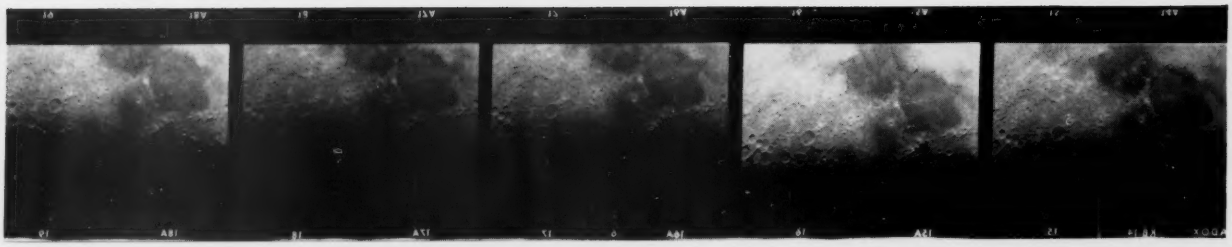
MOON PHASES AND DISTANCE

First quarter	December 7,	2:11
Full moon	December 15,	4:49
Last quarter	December 23,	3:28
New moon	December 29,	19:09
First quarter	January 5,	18:53

	Distance	Diameter
December		
Apogee 14, 7^h	252,600 mi.	29′ 24″
Perigee 29, 1^h	222,300 mi.	33′ 24″
January		
Apogee 10, 13^h	252,300 mi.	29′ 26″

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th, and to 10:15 p.m. PST on the 14th.



ON TAKING PHOTOGRAPHS WITH QUESTAR . . .

This picture of the moon is longer and wider than Questar's barrel. We have trimmed a grainless 8 x 10 print to fit this narrow space, but 16 x 20 enlargements with very little grain are practicable. Indeed, it is easy to hide Questar behind one of its own photographs.

Many people are astonished that such professional work can be done with our little 7-pound portable jewel of telescopes, whose aperture is only 89 mm. Hundreds of Questar owners use their versatile instruments in a variety of photographic ways. A recent and exotic use was the successful photographing of missile nose cones re-entering the atmosphere.

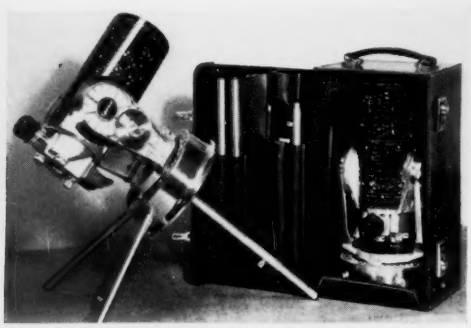
Questar's prime image of the moon is smaller than a dime, but this tiny image contains all the quality and detail that telescope and environment permit.

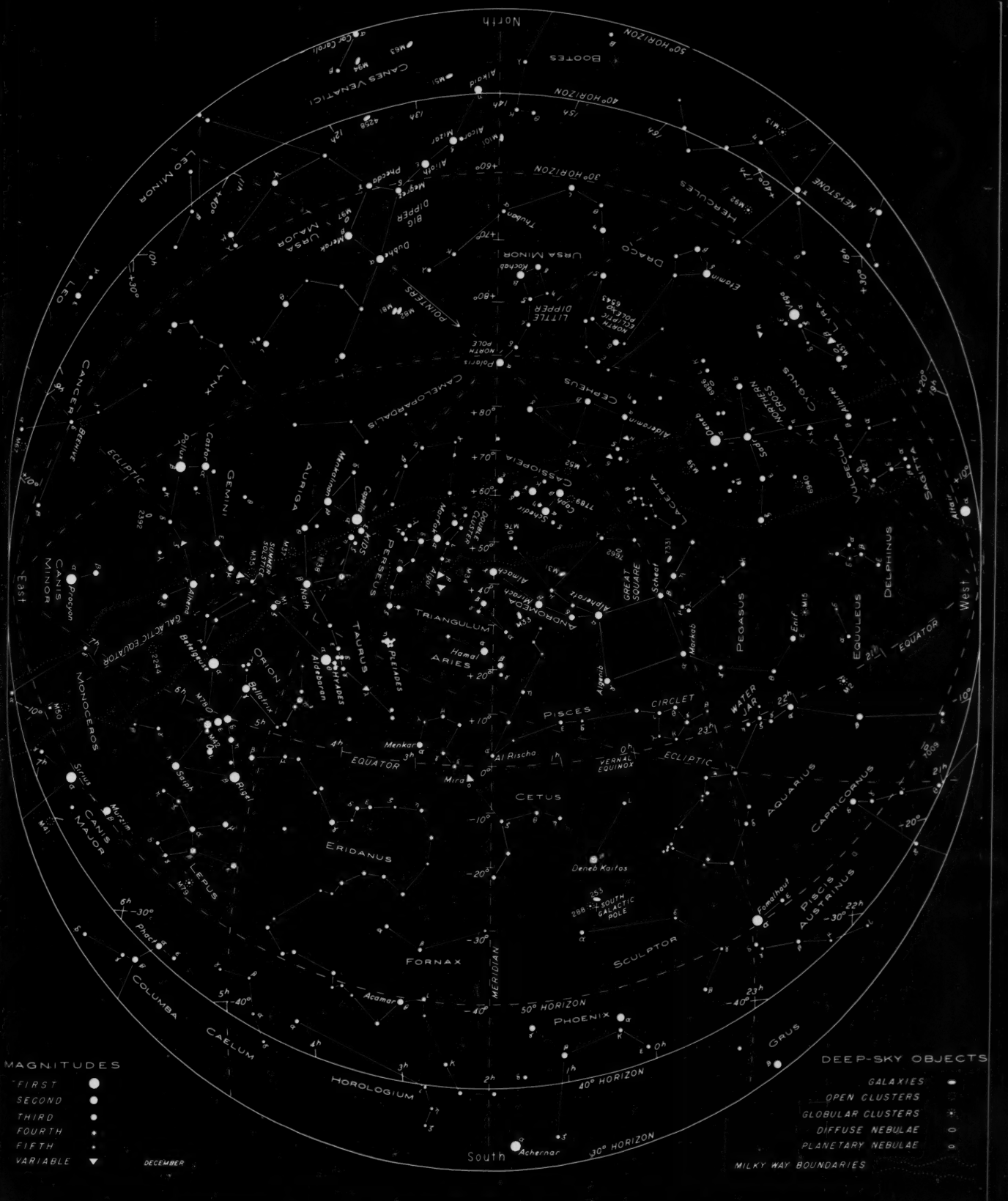
Taking pictures of the lunar disk can be a most rewarding avocation. However, it is no job for button pushers, for the "rules" keep changing, and the whole field is yours in which to try new ways to cut the losses inherent in the very process. Larger-scale negatives lose less in enlarging, so perhaps the best photographic resolution with the inexpensive 35-mm. film, as many Questar owners are discovering, is that obtained by means of eyepiece projection, which is described and illustrated in the Questar booklet published first in October '58.

A typical set of exposures by this method is shown in actual size above — note the variation in time and density. By thus using only part of the tiny prime-focus image and spreading it out over the whole film, excellent detail is captured even with exposures of as much as 15 seconds duration. Here Questar's relatively huge driving wheel (nearly half as big as the tube is long) insures perfect following. Questar's safety clutches are set lightly, too, so the movement will not falter from excessive friction. The operator must balance his camera load by some simple means, often by just weighting and adjusting the star chart, and try to shoot near the zenith where the seeing is always best.

Space forbids discussion of the many avenues one may explore. Much information is in our booklet, which also lists the several single-lens reflex-camera bodies that can be used with Questar. We will be very pleased to send you a copy without obligation. Questar still sells complete with fitted case for only $995 postpaid.

Questar New Hope Pennsylvania





STARS FOR DECEMBER

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 22nd of December, respectively; also, at 7 p.m. and 6 p.m. on January 6th and 22nd. For other dates, add or subtract ½ hour per week.

Cetus is now well placed in the southern sky; however, the famous variable Mira is below naked-eye visibility this month, having been at maximum in August. Inconspicuous Aries should be easily found, and Triangulum above it. To the southeast Eridanus is seen.

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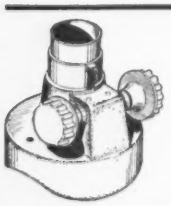

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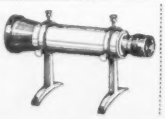

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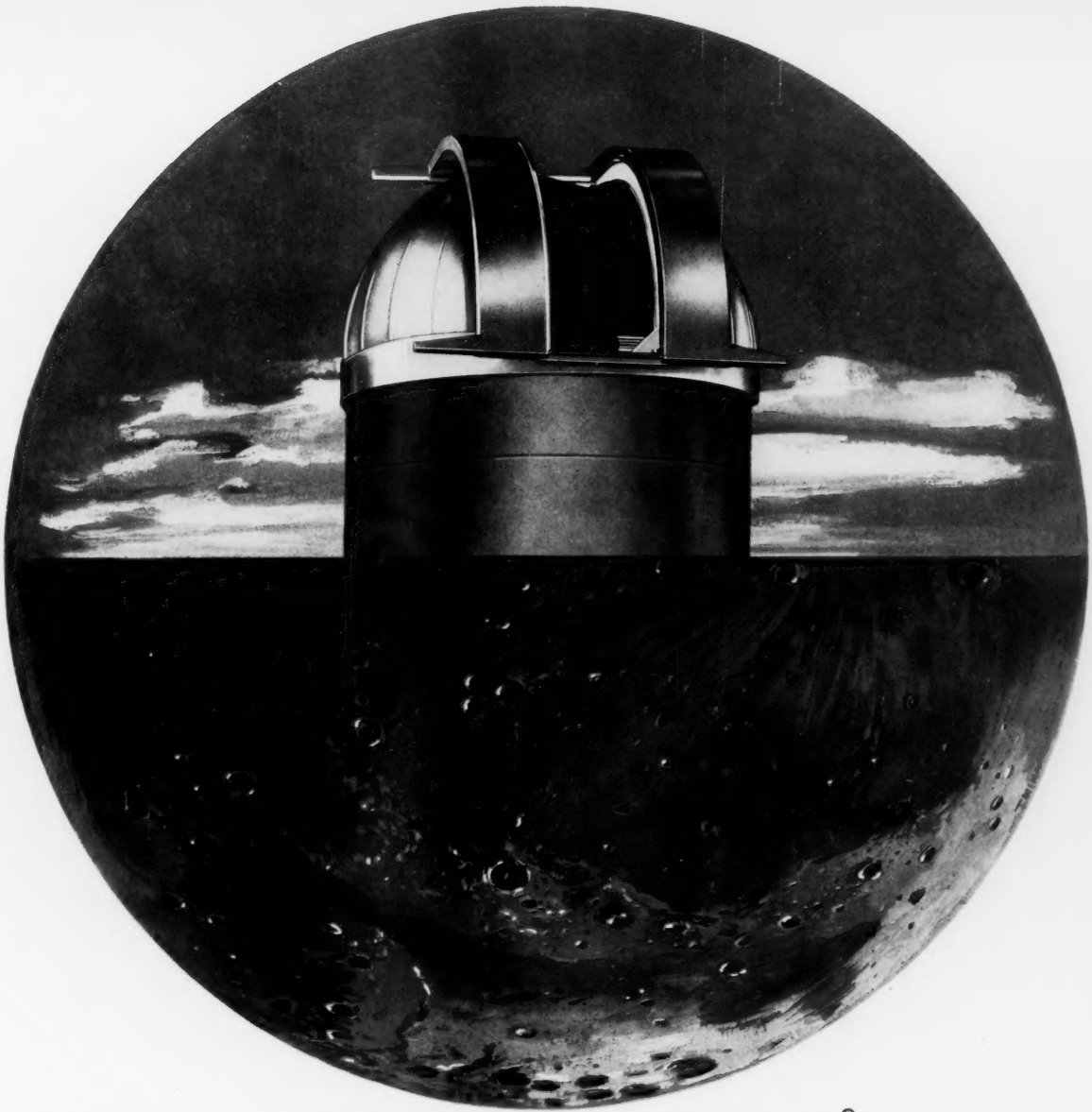

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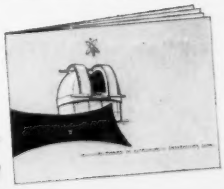

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With a Unitron, every night is Christmas Eve!

Who says Christmas comes but once a year? Certainly not any man, woman, or child who finds a Unitron under the tree. For in every handsome instrument with a Unitron label on it, there's a lifetime of pleasure . . . a trip to the stars every clear night of the year.

As a matter of fact, there's more pleasure-per-dollar in the Unitron 3-inch Altazimuth you see in this picture (or in any other Unitron) than you can find in any refractor anywhere on this planet of ours. How do we know?

Santa Claus told us. He says that there are more Unitrons delivered at Christmas (and throughout the year) than any other refractors.

To which all we can add is that the modest price tag on the Unitron in the picture is $265.00 complete. And . . . a very merry Christmas to all.

UNITRON INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO. — 204-206 MILK STREET, BOSTON 9, MASS.

SEE PAGES 128 AND 129 FOR MORE ABOUT UNITRON